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1906,

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 25.

THE PROSPECTS OF OBTAINING ARTESIAN WATER
IN THE
KIMBERLEY DISTRICT.

BY

R. LOGAN JACK,
L.L.D., F.G.S., F.R.G.S.

Issued under the authority of the Hon. H. Gregory, M.L.A, Minister for Mines.

WITH A GEOLOGICAL MAP.

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PREFATORY NOTE.

OWING to there being no officer of the Geological Survey Staff available, Dr. Jack was specially commissioned by the Public Works Department to report upon the prospects of obtaining artesian water in the Kimberley Division.

His report, and the explanatory map, on being submitted to the Government, were ordered to be printed for public information, as one of the series of the Geological Survey publications.

The index to names, places, etc., occurring in the report has been prepared by Mr. P. J. Atkins, Clerk of the Geological Survey.

A. GIBB MAITLAND,
Government Geologist.

Geological Survey Office,
Perth, 16th July, 1906.

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Geological Map ... ... At the end.

The Prospects of Obtaining Artesian Water in the Kimberley District.

I beg to report that, in accordance with my instructions, I left Perth and Fremantle on 29th October last and reached Wyndham by sea on 13th November. After making an examination of the neighbourhood of the township, and having completed my arrangements for the journey, I left Wyndham on 20th November, making for Derby overland, by a route determined by the object of the inquiry. Having arrived at Derby on 9th January, I embarked on the 17th and reached Perth on the 27th.

The details of the overland journey are given in the "Itinerary" appended to this Report, and may be followed on sheets 128, to 135, and 141 and 142 of the 300-Chain Map,* which have been geologically coloured; a reduced map on the scale of 12 miles per inch is attached. The main route amounted to 714 miles, with excursions by buggy, on horseback, or on foot, amounting to about 50 miles more. To the Itinerary there are added notes on the water supply at the camps (43 in number) and at various points along the route. These notes may be of service to future travellers, as they represent the actual condition of things during the severest drought which has yet been experienced by the white settlers of the district. The maps of the Lands Department show numerous "pools" and "springs" which I found dry, and which are not to be relied on except in good seasons.

The "wet season" of 1903-4 had been more or less a failure all over the district, and that of 1905-6 was, at the time of my visit, overdue, so that I saw the country at what it is to be hoped was its very worst. "Dry" camps, to which we had to carry water, had to be made if there was a prospect of feed for the horses. At other camps, we had to "spell" in order to allow the horses to recover from the effects of starvation stages behind, or to fortify themselves for similar stages in front of them. Moreover, as the intense heat (reaching 114 degrees F. and generally well over 100) made it impossible to work the horses between 10 a.m. and 3 p.m. without danger to their lives, valuable time had to be wasted. Under the circumstances, the route aimed at had often to be abandoned in favour of one determined by consideration of grass and water, and visits to certain desirable places had to be abandoned because neither of these necessaries was to be met with. We were, however, so far fortunate in that we now and then found water from local showers, although these had been either too light or too recent to produce any "spring" in the grass, while in the latter part of the journey rain had fallen long enough before we arrived to make feed abundant, and we suffered little inconvenience beyond an occasional wetting. None of the large rivers which lay across our path had begun to flow.

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* Lands Department Lithographs, 1904.

The main route (which is laid down on the maps) running south-east from Wyndham, touching the Northern Territory south of the 16th parallel, thence proceeding southward on the Western Australian side of the border to 16 degrees 25 minutes south latitude, south-westward to Hall's Creek, the metropolis of the Kimberley Goldfield, and westward and north-westward to Derby, kept, with slight exceptions, within the drainage areas of the two great rivers, the Ord and Fitzroy and their tributaries. The only inhabited places passed on the way were Goose Hill, Ivanhoe, Argyle, Rosewood, and McKellar's Stations, Argyle (Wild Dog) Police Station, Springvale, Texas, Ord River, Nicholson and Flora Valley Stations, Hall's Creek township and telegraph office, Langley's and Fossil Hill Stations, the Fitzroy telegraph office, the Fitzroy Crossing police station and hotel, Oscar Range, Balmaningarra and Meda Stations. Although considerable portions of this track are, as a rule, only used by travellers on horseback, the whole of it may be set down on the map as practicable for vehicles—provided the passengers carry with them a pick, shovel, and axe.

Geological Formations.

S. Carboniferous Sandstone.
L. Carboniferous (?) Limestone.
D. Devonian Sandstone, Grit, and Limestone.
M. Metamorphic Rocks:—Slates, Schists, Gneisses, etc. (Silurian, Cambro-Silurian or Cambrian).
G. Granite.
B. Basalt.

The pioneer geological observer was Mr. Edward T. Hardman, of H.M. Geological Survey of Ireland, who, in 1883 and 1884, accompanied the "Kimberley Survey Expedition," under Mr. Harry F. Johnston, now Surveyor General. Starting within a few days of his arrival in the colony, without any previous acquaintance with the Australian bush, and practically without maps—since the expedition was only laying the foundation of the excellent topography now available—Mr. Hardman, with a keen eye and intuition amounting to genius, sketched on broad lines the geological features of the district, at the same time pointing out its economic importance. It is true that the Kimberley Goldfield to which he directed attention has not taken, and may never take, a high rank, but his writings attracted the men whose further prospecting has resulted in Western Australia occupying a leading place among gold producers. He wrote two reports (1884 and 1885) "On the Geology of the Kimberley District," accompanied by two geological maps, the first embracing the district from Broome, *via* Derby, to Mount Fairbairn, and the second that from Mount Fairbairn north-eastward to the Northern Territory in latitude 17 degrees south. Although both reports and maps are of extreme value, they bear internal evidence that the printing had not the advantage of the author's supervision.

In 1891, Mr. Harry Page Woodward, then Government Geologist, traversed the country between Wyndham and the Goldfields, his observations supplementing those of Hardman, especially to the north and by a route west of my own, so that geological lines can be extended with confidence.

In 1901, Mr. A. Gibb Maitland, Government Geologist, went out in search of an alleged area of auriferous country between the 15th and 16th degrees of south latitude. No detailed report has yet been issued, but a synopsis is given in the Annual Report of the Geological Survey for 1901. Although Mr. Maitland's travels demonstrated the absence of the expected auriferous region, they were, as will be seen later, of high importance in their bearing on the question of artesian water.

Carboniferous (S.,L.).

This formation, as understood by Hardman, is divisible into an Upper or Sandstone (S.) and a Lower or Limestone (L.) series. The latter he describes as having been observed by him to be succeeded conformably by the former at the Haughton Range in latitude 19 S. and longitude 127 E. (Second Report, p. 27). All that I have seen is consistent with this order of succession. Hardman does not intend to convey, nor do I, that the Sandstone member consists entirely of sandstone, or the Limestone member of limestone. In the one, however, sandstone and other purely sedimentary rocks prevail, while in the other limestones predominate.

The *Upper or Sandstone series* (S.) was first seen by me at Wyndham and thence northward down the west arm of the estuary which widens out into Cambridge Gulf. It may be regarded as typically developed in the Bastion Ranges, at Wyndham. In these ranges, which attain a maximum elevation of 1,068 feet, escarpments of sandstone present their steepest faces to the north-west, and dip at a low angle, say seven degrees, to the south-east. Eastward, similar rocks (House Roof Hill, etc.) extend to the border of the Northern Territory. They are divided from rocks which I regard as Devonian by an east and west line running south of Wyndham and the " House Roof Crossing " of the Ord (*see* Sheet 142*). Mr. Maitland informs me that the Wyndham beds extend as a continuous formation westward to the mouth of the Prince Regent River, and have a prevailing dip to the west.

The sandstones themselves are white, although they frequently weather red or yellow, and are sometimes almost hard enough to deserve the name of quartzites. With them are associated shales, which form the bulk of the hills open to observation, although from their softness they are less conspicuous than the sandstones. The shales, so far as my observation goes, are absolutely unaltered, and are of the usual blue, grey, and black Carboniferous type, although they may weather to red or yellow.

In Sheet 141* only a very small area of the Upper Carboniferous rocks is met with between Mount Brooking and the border of the Northern Territory. Seventy miles farther to the south (Sheet 132*) the Upper Carboniferous forms the broken tableland of which Mount Elder is the most conspicuous fragment. The tableland lies between the Negri and Ord Rivers, both of which expose the underlying " Limestone " series. West of the Ord, the sandstones extend from the Glass Hill to the Dixon Range, presenting long cliffs surrounded by high " downs."

The formation is next met with at Flora Valley Station, east of Hall's Creek (Sheet 131*) where the sandstones rise to considerable elevations in Gullana Hill north and Mount Timperley south of the station, and the shales form open " downs."

Granite and Metamorphic and Devonian rocks, all older than Carboniferous, occupy the next 160 miles to the west along my route, and it is not till a few miles below the Fitzroy Crossing that the Upper Carboniferous formation re-appears. Here it is seen in juxtaposition to the Limestone or Lower member of the formation, and there is no reason to doubt that the latter underlies the former, as was observed by Hardman at Mount Abbott to the south-east. The line of demarcation between the two runs to the north-west, along the flanks of the Oscar and Napier Ranges, an enormous area of " pindan " country, diversified by sandstone tablelands, marking the extension of the Upper or Sandstone series of Carboniferous rocks from the George Range to Derby.

The *Lower or Limestone Member* (L.) of the series is not met with north of the Negri River. It occupies the valley of that River to the east of the Mount Elder Tableland, where it rises into Mount Panton (Northern Territory), and forms high "downs" up the valley of the Ord from its junction with the Negri south-westward to a point about five miles beyond the Hardman Range where it rests on bedded basalts.

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* Lands Department Lithographs, 1904.

From the "Rough Range" (Sheet 130*) north-westward to the Napier Range (Sheet 134*) the limestone series attain a most remarkable development. The Oscar Range, as seen from the south-west, shows a rectilinear rampart of limestone, 47 miles in length, which has all the appearance of being the edge of a horizontal tableland. This impression, however, is found, on close inspection, to be erroneous, as the limestone of the rampart is seen to rest unconformably on the slates and schists which compose the core of the range, and to dip to the south-west at 30 degrees. My route in this locality followed the telegraph line, which is carried along the flat at the foot of the "rampart." In this flat the dip of the limestone beds is seen to decrease to 15 and even 10 degrees, and there is every reason to believe that the limestones pass under the sandstones on the south-west side of the telegraph line. In the Geikie, Hull, and Rough Ranges (Sheets 129 and 130*), the outcrop of the Limestone series is many miles in breadth.

The Sandstone series, according to Hardman (Second Report, p. 25), contain an assemblage of fossils undoubtedly Carboniferous. The list from the Limestone series comprises fossils equally Carboniferous (Loc. cit., p. 26). Mr. H. A. Foord, however, in the Geological Magazine for 1900, describes several *Devonian* fossils presented by Hardman to the British Museum before his death. The fossils in question, according to the labels, came from the Rough Range and Mount Pierre, localities from which many of his Carboniferous fossils were derived.

At Minnie Pool (Sheet 130*), near Mount Pierre, I observed some indication that the limestone region mapped as Carboniferous consists partly of limestones of an older date. At the head of the Pool is a well-bedded limestone dipping to the west at 25 degrees. Between this point and the hill a quarter of a mile to the south, vertical beds of mica schist with a north and south strike are met with. The hill itself is composed of a limestone in beds which dip to the south-east at 80 degrees. Its strong Devonian aspect struck me at once. Some layers were almost entirely composed of corals in very bad preservation, but after a good deal of searching I obtained three specimens which I sent to Mr. Robert Etheridge, Director of the Australian Museum, Sydney. Mr. Etheridge writes that the corals are Stromatoporoids, and are, therefore, either Silurian or Devonian, certainly not Carboniferous.

There is always the possibility that Hardman's determinations —apparently made in the field—were less accurate than those of a palæontological specialist to whom the whole of the literature of the subject and the collections of museums are available. At the same time, I do not question his ability to appreciate the significance of the general *facies* of the assemblage of fossils with which he was dealing. Either there are, in the locality in question, separable Carboniferous and Devonian strata, or the same strata contain a Devono-Carboniferous, just as certain formations in the Eastern States contain a Carbonifero-Permian fauna. Any fuller discussion of this question would be out of place in a report dealing with the specific question of artesian water, on which it has no practical bearing.

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* Lands Department Lithographs, 1904.

Devonian (D).

· A formation clearly older, more highly metamorphosed, and more violently contorted than the Carboniferous, and yet neither so much metamorphosed nor so violently contorted as the slates and schists of the Goldfields, was provisionally referred by Hardman to the Devonian. It consists mainly of indurated sandstones, with beds of limestone. The sandstones are frequently so altered by the solution and redeposition of their silica that their original texture is either wholly obliterated or can only be recognised by following lines of coarser or finer grains, and in places may justly be designated "quartzites." Hardman first met with them in the south-western face of the King Leopold Ranges, which he followed from north-west of Mount Broome (Sheet 134*), south-westward to Mount Huxley and Mount Fairbairn (Sheet 130*). In this region, my route (in the opposite direction) joined his at Mount Fairbairn, where the sandstones have suffered (so far as I am aware) the extreme of metamorphism in the direction of quartzite. It is not surprising that he should have begun by classing this quartzite as part and parcel of the altered rocks of the Goldfields, and, as a matter of fact, in his first report and first map he did so. Subsequently, however, as he travelled east and north-east, he classed, in his second report, the *same* rock in the Albert Edward Range (where it is less altered) as Devonian. But for the absence of opportunity for revision and his untimely death, he would, in all probability, have altered his first map in accordance with the results of his newer observations.

In my traverse, the Devonian rocks were first met with at Goose Hill, 12 miles from Wyndham (Sheet 142*), and they occur to the south of a line drawn from that point eastward to the Northern Territory. They form the ranges on the left bank of the Ord River west of the Ivanhoe Stud Station, as far south as the slopes of Mount Hensman (Sheet 141*), where they abut on, and are evidently divided by, a fault from the "Siluro-Cambrian" slates and schists of the Carr Boyd Ranges. From Mr. Woodward's traverse, we are enabled to extend their area to the Saw and Deception Ranges, about 40 miles to the west. On the line of my traverse, they have a general dip to the east at about 30 degrees, while in the Saw Range they are highly contorted and dip to the north-west at 70 degrees. Where I saw them they were hard and quartzite-like on the surface, but when broken presented no very marked appearance of metamorphism.

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* Lands Department Lithographs, 1904.

So far as I could make out from my route, which here took me farther to the east, Mount Brooking and Mount Misery form a Devonian mass on the south-eastern side of the Carr Boyd Ranges. Woodward notes the occurrence of " Devonian Ridges " east of McPhee Creek, at and south of Trig. Station C.N. 8, and in this locality the Devonian rocks apparently rest on granite.

Farther to the south I traced a " wall " of highly inclined limestone from Rosewood Station south-westward to the Behn River, and was informed by Mr. F. C. Hill, of Lissadell Station, that it can be traced south-westward to near Mount Pitt, a total distance of about 45 miles. A similar " wall " runs south-south-west from the " Sugar Springs " for about 10 miles. Both of these masses stand up in the midst of basaltic " downs " precisely as if they were dykes or veins. It would, of course, be absurd to imagine them to be either the one or the other, and I can only suppose that they are " knife-edge " ridges of the old land surface, over the lower denuded portions of which the molten basic lavas were poured.

The Osmond Range, extending for about 40 miles south-west of the Negri River (Sheet 132*), although I only saw it from a distance, is obviously composed of rocks dipping south-south-east at 30 degrees, and identical with those of the Ivanhoe Stud Station, and I have no hesitation in mapping it as Devonian. It lies between gneisses and schists (Woodward) on the north-west and the Carboniferous rocks (Upper and Lower series) of the Ord Valley. In all probability some of the ranges between Osmond and Turkey Creek are of the same age.

The Albert Edward Range, occupying the left (west) bank of the Elvire River (Sheets 131 and 132*), and flanked on the west by the slates, schists, etc., of the Goldfield, is composed of grits, sandstones, shales, and limestones. The sandy beds which greatly predominate, are somewhat indurated, but cannot, except occasionally, be spoken of as " quartzites." The strata have a prevailing south-south-westerly dip, varying from 20 to 45 degrees, and frequently coincident with the slope of the eastern side of the range.

The Hardman Range (Sheet 132*), is composed of rocks identical with those of the Albert Edward, although coloured on Hardman's map as Upper Carboniferous limestone " downs," and is evidently a portion of an old land surface too high to be covered by the deposit of Lower Carboniferous limestone. It is impossible to explain, otherwise than by hurried observations, Hardman's identification of this range with the Upper Carboniferous. The range is composed of indurated sandstones precisely similar to the rocks of the Albert Edward Range, which he has mapped as Devonian, and absolutely unlike anything which he has mapped elsewhere as Carboniferous.

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* Lands Department Lithographs, 1904.

From the Albert Edward Range westward through the slates of the Hall's Creek Goldfield and the granite which divides the Elvire and Laura drainage basins, nothing more is seen of the Devonian formation. It re-appears, however, in a low range west of the head of the Laura (Sheet 130*), where it consists of indurated sandstones of the Albert Edward type. Hardman maps it as "quartzites and altered grits" of Lower Silurian or Cambro-Silurian age, and includes Mount Barrett, to the north-east, in the same mass. Although I have only seen Mount Barrett from a distance, it is so obviously different from the indurated sandstones of the head of the Laura that I hesitate to regard it as of the same age.

The Ramsay Range (Sheet 130*), composed, according to Hardman, of "hard red grits," is mapped by him as Devonian. As seen by me from the north-east it appeared to be identical with the Laura mass, the strata dipping at 20 degrees to the north-west.

Masses of granite, gneiss, and schists intervene between the Laura and Dead Horse Creek (241 mile post of the telegraph line), where the next outcrop of the Devonian rocks is crossed. This place is on the summit of an anticlinal arch, the indurated sandstones dipping to the north to form the Mueller Range and to the south to form low hills which have not been dignified with a name. Farther west, it will be noticed that the indurated sandstones of the Mueller Range, dipping to the north-west, are absolutely continuous with those of the Lubbock Range dipping to the south-east. Hardman has, however, mapped the former as "quartzite and altered grit" of "Silurian or Cambro-Silurian" age, and the latter as Devonian. In his report Hardman insists on the identity of the Mueller Range with the King Leopold Range, with which I entirely agree, in so far as the southern end of the latter (which is all that I have seen) is concerned. In my view, the Lubbock Range and the Mueller Range (and therefore the King Leopold Range) are newer than the "Silurian or Cambro-Silurian" rocks of the Goldfields, and identical with the Albert Edward Range, which I agree with Hardman in calling Devonian.

Mount Bertram, west of the Lubbock Range, consisting of "hard brown grits and flags, with slates and limestones rolling at high angles," is also mapped by Hardman as Devonian.

The gorge of the Margaret River, dividing the Mueller from the King Leopold Range, shows beds of white hardened grits, dipping at high angles to the north-west. About ten miles farther, similar sandstones, indurated to the point of being almost quartzites, form a sharp anticline. the strata on the north being part of the King Leopold Range and those on the south being almost immediately faulted against a granitic mass.

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* Lands Department Lithographs, 1904.

Lest it should appear that the above remarks are mainly a criticism of Hardman's report and maps, I should like to make it clear that no one is more fully aware of their value than I am. At the same time I may say that, if I have made corrections, I believe that they are only such as, had Hardman lived to review his completed labours, he would himself have made. The advantage which I had over him in having in my possession fairly reliable maps, while he had practically none, is one which only a field geologist can fully realise.

Silurian, Cambro-Silurian, or Cambrian (M).

Large areas of metamorphic rocks, slatey, schistose, and gneissic, were provisionally regarded by Hardman as Lower Silurian or Cambro-Silurian. and in these occur the auriferous veins of the Kimberley Goldfields. There is little physical evidence as to their age, beyond the fact that they are overlaid by Devonian rocks. The palæontological evidence is also exceedingly meagre, and, scientifically speaking, ought to be ignored, as the two localities from which Hardman collected Cambrian fossils (*Salterella Hardmani* and *Olenellus ? Forresti*), have been defined too vaguely for identification as "Kimberley District" and "River south of Base Line." As the only way in which these rocks affect the question now at issue is that they cover an area in which artesian water is not to be expected, they may be passed over with the mere record of where they occur.

They were first met with by me at Mount Hensman (Sheet 141*), and it is believed that they form the whole or the greater part of the Carr Boyd Ranges. Next they form a broad belt extending between the granite of the upper waters of the Ord on the north-west and the Devonian and Carboniferous rocks on the south-east, from the Negri River south-westward to, and beyond, the Hall's Creek Goldfield and the McClintock Range (Sheets 132, 131, and 130*). Isolated patches are met with in the Laura and Margaret valleys (Sheet 130*), where, at least in some instances, they pass into granites. They then, according to Hardman, form a broad belt extending to the north-west from the Margaret River near Mount Krauss to Mount Amy on the Barker River (Sheets 130, 133, and 134*). This area, which includes the auriferous rocks of Richenda, is beyond my personal knowledge, with the exception of part of the Oscar Range, where the slates, etc., underlie the Carboniferous (?) limestone.

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* **Lands Department Lithographs. 1904.**

Granite (G).

No less "out of it," as regards artesian water possibilities, are the granites which lie mainly west and north-west of my route. According to Woodward and Hardman, an extensive area of this rock stretches from near the junction of McPhee Creek with the Denham River south-westward to the head of the Elvire River, (Sheets 141, 132, 133, 131, and 130*), a distance of over 150 miles. I crossed the prolongation of this belt west of Hall's Creek on the upper waters of the Laura and Margaret (Sheet 130*). Further patches were traversed along the telegraph line, west of Dead Horse Creek, and from the gorge of the Margaret, between the Mueller and King Leopold Ranges, to Minnie Pool (Sheet 130*) In the region thus known to me the granite evidently represents the ultimate stage of metamorphism of the sedimentary "Silurian, Cambro-Silurian or Cambrian" rocks.

Basaltic Rocks (B).

The western edge of what was designated by Hardman "the Great Antrim Plateau," an area consisting essentially of bedded basic lavas, is mapped by him as extending from a point east of Flora Valley Station (Sheet 131*), north-eastward to Mount Napier in the Northern Territory (Sheet 132*). He then brings it, with a sweep to the east, north, and west, back to Western Australia north of the Negri River (Sheet 132*), and after making it include Mount Close and its vicinity, takes it again into the Northern Territory in lat. 16 degrees 45 minutes south (Sheet 132*), a little north of the northernmost limit of his journey. Travelling, as I did, from north to south, I first came on the basaltic area at "Pickle Bottle" camp, 16 degrees 4 minutes south (Sheet 141*), and followed it along the border for 47 miles to the point where Hardman places its northern limit.

From a lithological standpoint, the name "basalt" is not sufficiently comprehensive. Hardman describes the assemblage of volcanic rocks as consisting of "many varieties of basalt, including dolerite and anamesite, trachy-dolerites, lavas, volcanic breccias, and ash beds, ferruginous wackenite, etc.," and it is certain that he has by no means exhausted the list.

As regards its age, Hardman says (2nd report, p. 19): "That it is of intermediate age between the Carboniferous and the supposed Devonian rocks is certain, for within a short distance it is found resting on the one, and covered by the rocks of the other formation, as at the junction (and a few miles below it) of the Panton and Elvire. At J/38 the limestone is also seen resting on the trap rock." (Sheet 132*).

My own route lay a few miles above (*i.e.*, south of) the junction of the Panton and Elvire, and here also I found the basalt emerging from beneath the Carboniferous (?) limestones, and four miles farther west overlying the Devonian sandstones. For nearly 40 miles to the south I saw the Devonian rocks dipping beneath the basalt. The Antrim Plateau, therefore, as far as Hardman saw it, must be approximately on the horizon he ascribes to it. I have, nevertheless, grave doubts whether the almost equally extensive area of basaltic downs (as far as Western Australia is concerned) which I traced from "Pickle Bottle" camp to the right bank of the Negri River is not of much later date. In the latter region, the lava has all the appearance of having simply levelled up a depression formed by the converging Bow and Ord Rivers. If the two basaltic areas are really continuous, I cannot help thinking that there is merely an accidental apposition of two similar masses of widely different ages, the one Devonian and the other probably Tertiary. In what may be called the Argyle area (since the greater part of it is included in the run of that name), the basaltic beds are nearly horizontal and, as far as I can see, overlie the Carboniferous (?) limestone of the Negri Valley. They have covered over the old surface of the Ord River valley with the exception of certain "knife-edge" ridges of Devonian(?) limestone which still protrudes above its level, while other underlying limestone masses (near Argyle Station) have been disclosed by denudation in the bed of the Ord River and its vicinity.

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* Land Department Lithographs, 1904.

There is some probability that the basalts of this Argyle area were not wholly the result of one continuous period of volcanic activity. Just above what is known as the "Gorge" of the Behn River, between Rosewood Station and Mount Quirk, is a dome or "puy" of basalt, apparently the centre from which issued the lavas that dip away from it to the south-west and north-east. These basalts must have been less fluid than the older beds which form the mass of the Argyle area, since their comparatively rapid solidification has given rise to a thickening in the neighbourhood of the vent and a thinning out as they get farther away, whereas the beds on which they rest appear to have reached, with undiminished fluidity, the limits of the depression into which they were poured.

In a word, I regard the basalts of the Argyle area as probably Tertiary, and as the newest of all the formations represented in the Kimberley district, with the exception of "Pindan" and Recent Alluvium, and possibly the "Upper Tertiary" limestone detected by Hardman on the summit of one of the eminences of the Mount Elder Range.

From the Geological Map accompanying this report, "Alluvium" and "Pindan" have been eliminated. The "Alluvium" is really of very limited area, although Hardman has designated wide regions by the same colour as those "where soils are largely distributed." He had naturally never seen "downs" or the extensive scale on which they are developed from the decomposition of limestones and certain igneous rocks in Australia, and did not realise that they are simply decomposition products *in situ*. The very large area which he has coloured as " Pindan Gravels and Boulder Beds " marks an instance of the decomposition *in situ* (with the occasional addition of " surface wash ") of sandy and gravelly rocks, mainly Upper Carboniferous. " Pindan " it may be explained, is supposed to be an aboriginal word, but is now locally used by the white population to distinguish lightly timbered rolling sandy country. To make " formation " of " pindan " or " downs " merely tends to obscure our conceptions of the actual geological structure.

Artesian Water Possibilities.

(1.) Wyndham.

The Carboniferous rocks of Wyndham consist principally of dark bluish-grey shales, varying in thickness up to 100 feet. Where these rocks rise into mountain masses, the fact is due to denudation having been arrested by the outcropping of sandstone beds, which are naturally more resistant than the shales. It is usual to refer to the local mountains as " flat-topped " or " sandstone-capped " hills, but the flatness of the strata is only apparent, the rocks, as a matter of fact, generally having a gentle dip. In the immediate vicinity of Wyndham the dip is to the south-east (*e.g.*, in the Bastion Range), although to the eye of an observer placed on the north-west the outcrop of any conspicuous bed appears to be strictly horizontal.

Of the conditions favourable to the existence of artesian matter some of the most important are present at Wyndham.

These are :—

(1). The occurrence of alternating strata of shale (consolidated clay, to all intents and purposes impermeable) with sandstones (more or less permeable) and

(2). A dip such as may carry permeable beds from their outcrops in the mountains to not inaccessible depths beneath the places where water is required.

The problem, as regards Wyndham, may be thus formulated. At this port cattle are shipped in large numbers but under conditions of severe hardship. The cattle get no water to drink, as a rule, between the " Twelve-mile " and the steamer. Should any delay occur in shipping, there is nothing for it but to drive the animals back to the water. One instance of a mob having been driven to and from the port for ten consecutive days was related to me.

For the limited human population, rain water and wells, supplemented if necessary, by the distillation of sea water, might suffice, but thousands of cattle cannot thus be provided for.

Something has already been done, or at least attempted, to meet the difficulty, but the experiments have been attended with more expense than success.

Wells have been sunk: (1) behind the Courthouse, (2) behind the Gaol, and (3) in the valley between the West Bastion and Mount Albany.

The court-house well was (on 19th November last) nearly dry. The water was good but the collecting of a bucketful took a long time.

The gaol well (96 feet deep) has a more copious supply (3,000 gallons per day) but the water is too brackish for human consumption, although thirsty horses will drink a little of it. It is said to become distinctly salter at spring tides. A bore was sunk 594 feet further, but no more water was met with.

From the section given in "Description and Diagrams of Bores for Water and Coal to 30th June, 1900, Public Works Department," it will be seen that shales (sometimes called slates) were almost exclusively met with in the upper half of the bore, while in the lower half "hard grey crystalline sandstone" with slate (shale) bands were the prevailing rocks. In the few fragments of core which I have been able to see the shales are not at all altered, nor are the sandstones extravagantly hard.

The well (Dilyan Springs) in the valley between Mount Bastion and Mount Albany was dry on 16th November. It has been fitted with a windmill which, when there is water, delivers into a service tank at the gaol. The town has also been reticulated with pipes in anticipation of a supply which was not forthcoming.

Two of the conditions upon which artesian water depends may now be discussed, viz.:—(*a.*) Are there to be found beneath the site of a bore strata which rise to an outcrop on a still more elevated site? and (*b.*) Are these strata sufficiently open to admit of the passage of water?

(*a.*) Assuming a seaside site in Section 82 of the township (selected for reasons afterwards given) and a continuation of the observed rise of the strata (7 deg.) to the north-west, a bore 4,000 feet deep would cut 3,970 feet of strata, among which there is reason to believe some thick beds of sandstone or conglomerate would be met with, such beds rising to their outcrops in the high ground bounded on the east by the west arm of Cambridge Gulf, on the north by the Forrest River, and on the west by the Ernest River.

(*b.*) The thick sandstone forming the " cap " of the West Bastion is fairly hard and close-grained, and (the grains of sand having been recemented by dissolved silica) would be described by many, without hesitation, as " quartzite," and the conclusion would be arrived at that it would prove impermeable to water. It is, however, no uncommon experience in tropical countries that sandstones intensely hard and close on the surface prove comparatively soft and open at a depth. As specific instances within my own knowledge may be mentioned the sandstones at Croydon and Montalbion (Queensland). The marked difference in hardness between the Devonian sandstones of the surface and similar sandstones at the depth of 65 feet observed during my journey in a well near Emu Springs is another case in point. My theory on the subject is that the superficial water, being much warmer than in temperate latitudes, dissolves a great deal of silica which, on redeposition, tends to close up the interstices of the rock, but that this is only a superficial phenomenon.

I was informed by Mr. Cunningham, late postmaster at Wyndham, that the sandstone beds met with in the Gaol bore were in some instances soft enough to be named " sand " by the borers, although the record of the bore makes no mention of such beds. If they actually occurred, the inquiry will be made, " Why, then, did they not carry water ? " The explanation may be that these strata crop out under the Gulf, whose muddy bottom prevents their becoming water-conveying channels.

Mr. A. Gibb Maitland, Government Geologist, having travelled extensively in the region west of Wyndham, I felt sure that his observations must have furnished important data on the question of the outcrops of the strata underlying Wyndham. Having been communicated with by telegram, his reply (from Marble Bar, 17th November) was as follows :—

> Wyndham beds extend as continuous formation west to mouth of Prince Regent River and from Mt. Hart on Leopold Range north to Admiralty Gulf. Beds have prevailing dip North-West, and comprise quartzite, grits, conglomerates, with interbedded igneous rocks. Am afraid not porous enough.

The south-west dip in the Bastion Range, and the north-west dip observed farther west by Mr. Maitland, point to the existence of an anticlinical arch, which at any rate, must be west of the Ernest River. The south-eastern slope of such an arch would expose, in high country, the outcrops of strata which would pass, and, it may be hoped, carry water, beneath Wyndham.

Mr. H. P. Woodward, then Government Geologist, reporting in 1891 on the " Goldfields of Kimberley District," expressed an opinion in favour of the prospects of artesian water at Wyndham, although he does not seem to have based his conclusions on any dip of the Carboniferous strata (which, in fact, he refers to as horizontal). His exact words (p. 8) are:—

> In the Northern portion of this district (near Wyndham) the rocks are horizontally bedded, the water supply being obtained on the top of, or a little way into, shale beds beneath which the whole subterranean drainage from the interior passes. Therefore, if a bore were put through these beds a large supply would be encountered which would rise to the sea-level, if it did not rise a good height above the surface; in fact this is an artesian area.

In my view, water would rise to the level of the " head of water " (the outcrop of the stratum) or, where the rim of the artesian basin is partly depressed or broken, to the " hydraulic surface," viz., a line drawn from the head of water (intake) to the outlet or leak.

SITE OF BORE.—The thick sandstone bed near the summit of Mount Bastion dips, as has been observed, at about 7 degrees to the south-east. As the valley of the West Arm cuts through this stratum obliquely to the strike of the sandstone, the latter is found to the south capping hills at lower elevations. Approximately, its base on the West Bastion is 1,000 feet above sea-level, while at Mount Albany it is only 400 feet.

The gaol well and bore give a section of 690 feet of strata, commencing about 4,000 feet below the horizon of the sandstone. On the site recommended (Section 82 *) a bore would commence about 1,000 feet below the sandstone, and would thus have 600 feet of an advantage over a bore at the gaol, beginning about 90 feet above where the gaol bore left off.

Even such an apparently small amount as 600 feet may make an important difference when it is considered that 4,000 or 5,000 feet may be taken as the limit of practicable and economical boring.

Mr. Gibb Maitland, in " Report of the Geological Survey for 1902," gives a section of the strata from Mount Albion to the Three-mile. The section of the strata dipping from the former to the latter is pierced, near the Three-mile, by an intrusive mass of basalt, on which he remarks that " any water received on the northern face of the range and percolating down the dips would be checked by this wall of impervious rock, behind which it would tend to accumulate until the water is thrown out by springs." Should such an intrusion of impermeable rock interrupt strata which crop out at high altitudes *west* of the face of the Range, a situation ideally favourable to artesian water would be created, *unless* similar intrusions to the west should be found to *shut off* the water from the supposed strata.

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* Section 82 of the surveyed township. The existing buildings are on a much less suitable site.

I am of opinion that, although unforeseen difficulties, such as igneous dykes or close-grained rocks, may lead to failure, *all that is ascertainable* gives strong grounds for hoping that a deep bore would meet with success. A successful artesian bore would be the only adequate solution (short of a pumping scheme) of the stock water difficulty which now so seriously retards the progress of Wyndham.

At the same time it would be worth while, before committing the Government to a large expenditure on what is, after all, *a chance* (although in my opinion a good chance) to estimate the cost of a water supply pumped up from the springs at the Gut and conveyed in pipes to the township. The distance as the crow flies is about seven miles.

(2.) Country East and North-East of Wyndham.

In the southern portion of this region (Sheet 142*) the Ord River has, I believe, a permanent supply of water, serviceable as far as stock can feed back from the frontage.

Should artesian water coming from outcrops far to the west be found at Wyndham, it should be found here also but at greater depths, calculable by the distance and the average dip of seven degrees. I should not advise boring here until after an experiment at Wyndham.

The prospects of artesian water being found at shallow depths would depend on water taken in by the outcrops of local eminences to the west, which are, so far as my knowledge extends, too limited in area to furnish any supply of importance.

(3.) Devonian Region between Wyndham and the Carr-Boyd Ranges.

In this region (Sheets 142 and 141*) the prevailing rocks are indurated sandstones, frequently approaching the character of quartzites, in beds which are parted by accumulations of shale. My traverse has made me fairly well acquainted with its eastern portion (extending to about 35 miles west of the Northern Territory), but of the western part my knowledge is limited to what has been put on record by Woodward regarding the Saw and Deception Ranges and what I have myself seen of Mount Erskine from the north. Mount Erskine appears to consist of the usual sandstones and shales bent into an anticlinal arch, the strata dipping to north-west and south-east. In the Saw Range, according to Woodward, the dip is to the west, while farther east it is in the opposite direction, so that here also there must be an anticlinal arch. From Goose Hill eastward to the north and south reach of the Ord River opposite Ivanhoe Stud Station the strata dip to the east, or a little to the north of east, at an average of 30 degrees, forming a mass of rugged hills to the west of the river. These hills rise, I should judge, to about 600 feet above the sea level, on an average, and follow the west or left bank of the river for 20 miles. At one point (H.J.8 on Sheet 142*) the altitude is given on the map as 958 feet.

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* Lands Department Lithographs, 1904.

The land on the eastern side of the river, except for isolated eminences, is at a much lower level than that on the western, but is evidently formed from similar rocks. I should judge the bulk of it to be not more than 250 feet (the level of Emu Springs). Emu Springs (Sheet 142*), it may be mentioned, are " well eyes " in a pandanus swamp, and I cannot account for them otherwise than by supposing that the water is brought to the surface by some obstruction such as an igneous dyke concealed by the soil. About 3½ miles east of the springs I found a party (Torrance and Smith) engaged in sinking a well for the road board. It was down 65 feet, the contract being 85 feet, and no water had, so far, been met with. Although the sinkers called the sandstone " hard," it was soft by comparison with the outcrops of the Devonian beds, and of an open texture favourable enough to the passage or storage of water. The Eight-mile Well, 5½ miles to the south-east, is sunk 65 feet in sandstone not quite so soft as that of the other. The water is slightly salt but not too much so for drinking purposes. Cockatoo Springs (Sheet 141*) are similar to Emu Springs, the soil concealing all evidences of the source of the water.

In this region, east of the river (*provided a low site were selected*), I should expect artesian water at no great depth, its source being the elevated outcrops of sandstone extending south from Button's Gap and westward. The only circumstance to cause uneasiness is the supposed hardness of the strata, which seems to be disproved, or at least its probability lessened, by the experience obtained in sinking the wells above referred to.

(4.) The " Argyle " Basaltic Area.

This area, or at any rate the Western Australian portion of it (Sheets 141 and 132*), is fairly well supplied with surface water. The Behn, Ord, and Bow rivers traverse it from south to north, and all, especially the two last-named, have what I believe to be " permanent " water-holes. Again, although I have not seen the locality, there should, if one may judge from the map, be no engineering difficulty in fluming water from the " copious very hot springs " 13 miles west of Lissadell Station to supply a portion of the run. There are, however, portions of considerable extent where grass grows, and yet water is too far distant for stock, so that it is possible that artesian water may be among the requirements of the future.

It has already been said that I regard the basalts of this region as having fillen up a depression in the neighbourhood of the junction of the Ord and Bow. The surface over which the molten basaltic lavas were poured out was, no doubt, composed of Devonian and Silurian, or still older, Metamorphic rocks. The Ord and Bow must have been compelled to cut out new channels for themselves after their valleys had been filled up with basalt.

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* Lands Department Lithographs, 1904.

The attitude of the lower edge of the basalt is a factor of high importance in the calculation of the chances of obtaining artesian water, and it is unfortunate that very few data on this subject are available. Presumably the highest point is about the spot where the road from the Wild Dog Police Station crosses it north of the Negri River, and this point may be assumed, from readings in the vicinity, to be about 650 feet above the sea. Argyle Station, by the same aneroid, is 380 feet, and the river at the northern end of the area will therefore be about 300 feet. These readings would, in the distance of 56 miles separating the two points in question, give a fall of 350 feet, or 1 in 845. Supposing the drainage of the high Silurian (or older) land to the south to flow partly underground between the old surface and its present basaltic covering, or to enter any comparatively porous beds of the volcanic series (such as tuffs or scoriaceous lavas), artesian water would be tapped by a bore in any locality where the surface was lower than the intake. It may be argued that a grade of 1 in 845 is very slight for a flow of water, but evidence is not wanting that in spite of the lowness of the grade water *does* flow in or beneath the basalt. Springs rise to the surface at the police station and at the so-called " Sugar " Springs. The water at both places is apparently brought to the surface by the obstruction put in the way of its northward flow by the limestone barrier standing up above the basalt and forming a portion of the old, hard, pre-basaltic surface. It may here be noted that the " Sugar " Springs, five or six in number, rise out of the basalt east of the limestone. They have recently been opened out by the Public Works Department, and the water led into trenches which ultimately direct it into a creek, with the result that a permanent, if limited, supply for travellers and cattle is assured. An attempt was also made to bore for artesian water, but the hand-drills employed were found to be incapable of piercing the basalt to a greater depth than 40 feet.

It might naturally be supposed that the barrier of pre-basaltic land represented by the Rosewood limestone wall would effectually block the flow of underground water to the north-west. But that the flow is *not* blocked is proved by the occurrence of the Stockade Creek " Soda " Springs. These are similar in character to the " Sugar " Springs, although on a larger scale, and make a waterhole nearly a quarter of a mile in length. Nothing is seen to account for the water rising to the surface, but it may be assumed that a barrier of some hard pre-basaltic rock, such as is visible beside the " Sugar " Springs, exists beneath the soil. Limestone, in fact, is seen on the track between the Springs and Argyle Station, not very far from the Springs. That the underground flow of water is not stopped by the Rosewood " wall," shows that the wall, although coloured on the map (from information supplied) as continuous, must be breached in one or more places—must, in fact, have been cut through by the Ord or its tributaries prior to the out-pouring of the basalt.

Reviewing the whole of the evidence, I am inclined to believe that artesian water may be obtained in any part of the Argyle basaltic area where the surface is not higher than the intake. In view of the insufficient *data* existing regarding altitudes in this region, I should, however, recommend that, before the expense of boring is incurred, levels should be taken between any proposed bore site and some definite and fairly high portion of the " intake," such as the point where the road from the police station to Texas (Kelly's Station) crosses the southern limit of the basalt north of the Negri. The hardness of the basalt must be taken into account in estimating the cost of boring, but I believe that the basalt is of no great thickness—probably less than 300 feet--except in places such as Mount Quirk, Mount Evelyn, Mount Close, and the hills between the 14-mile Creek and Spring Creek.

(5.) The Great Antrim Basaltic Plateau.

From the relative altitudes of the eminence J 32 on the top of the plateau (1,661 feet) and the junction of the base of the basalt with the top of the Devonian formation near the Camel Creek Yard (about 1,000 feet), the total thickness of the basaltic beds may be taken to be at least 660 feet. Hardman's estimate (Second Report, p. 18) is 1,126 feet, and it is probable that, as a maximum, this is within the mark. But in questions of boring it is not the maximum thickness deposited, but the minimum to which the formation has been denuded that has to be taken into account. Should the " dip " of the basaltic beds, as seen on the eastern edge of the plateau (about 20 degrees), persist for any distance to the east, the thickness of the basalt would soon be enormously increased, but there is reason to believe that the dip flattens to the east, and, according to Hardman's observations, the beds must swing round to dip beneath the Carboniferous(?) limestone of the Nicholson Valley.

The line along which the Devonian sandstones dip beneath the basalts of the plateau has an approximate elevation above sea-level of from 1,200 feet opposite Flora Valley Station to 800 feet near the junction of the Panton and Elvire Rivers.

The grits and sandstones of the Devonian formation of the Albert Edward Range, dipping to the east and traversed along their strike by the Elvire River, are (unless they are too close-grained, which is more than doubtful) disposed in the most favourable manner conceivable for carrying water beneath the basaltic plateau. The sedimentary Devonian rocks in the west of the Albert Edward

Range, where they abut on the older metamorphic rocks, dip to the east, or south-east, at high angles, but the dip diminishes to the east until, at its junction with the basalt it is not more than 20 degrees, the basalt itself dipping at the same angle. If the basalts are interbedded with the Devonian rocks, or succeeed them, so to speak, "conformably," and if we accept Hardman's view that the basalts turn round and dip to the north-west, the Devonian rocks must, not many miles east of the Elvire, flatten out and form a basin beneath the plateau.

No condition more favourable to the existence of artesian water could be imagined, but it must be admitted that there is a good deal of the theoretical about it. I should not advise boring on the plateau untill a mass of information, still wanting, has been accumulated with the object of throwing light on the dip and thickness of the basalt. A good many lines might be run from the Elvire across the plateau, and accurately levelled for less than the cost of a single unsuccessful deep bore in hard country.

At the same time anyone who is inclined to "chance it," in a sporting spirit, may have the luck to hit upon comparatively shallow artesian water (probably very limited in amount) derived from the outcrop of some elevated porous volcanic bed within the area of the plateau itself. Personally I should much prefer the compilation of reliable data, followed by logical reasoning.

(6.) The Carboniferous (?) Limestone Area between the Junction of the Negri and Ord Rivers and the head of the Turner.

This formation (Sheet 132*), in which beds of limestone predominate over the sandstone and shale beds, and give rise to extensive "downs" (mapped by Hardman as "Recent"), is seen overlying the basalt between the Hardman Range, and the Elvire River, and, according to Hardman, it bears the same relation to the basalt of the Great Antrim Plateau north-east of the head of the Turner. Its basal beds must, therefore, have an elevation of between 1,000 and 1,200 feet. The greater part of the extensive "downs" between the plateau and the Ord River does not rise above 600 to 800 feet. The strata, which at the south-western and south-eastern boundary of the formation dip to the north-east and north-west, are practically horizontal on the Ord River below its junction with the Elvire, and probably continue to be horizontal where they are covered, on the left bank of the Ord, by the upper or sandstone member of the Carboniferous series until they are faulted against the metamorphic rocks north-west of the Dixon Range. Such a disposition of the strata, supposing some of them to be sufficiently porous, is favourable to the occurrence of artesian water, and become artesian on being released by bores. The success of boring operations will depend (1) upon whether or not porous beds occur near the base of the formation, and (2) whether there are water-bearing channels in the limestone itself. As regards the first, all that I can say is that between the Hardman Range and the Elvire River the basal beds are limestone and not sandstone. On the other hand, there are flaggy sandstones in the "downs" between Forrest creek and the Ord River, and there may very well be thick and porous beds in the formation which did not come under my eye. In the alternative case, it is well known that almost every extensive limestone deposit is channelled with underground watercourses. To strike one of these in a bore is, of course, purely a matter of luck.

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* Lands Department Lithographs, 1904.

Failing artesian water in the formation itself, there is a chance of finding it by penetrating the underlying basalts and reaching the Devonian sandstones. To this course it is more than likely that the thickness of the basalts, added to that of the limestone formation itself, will form an insuperable obstacle. At all events it would be well to await definite information as to the thickness of the basalt before making the experiment.

(7.) The Carboniferous Sandstone Area between Glass Hill and the Dixon Range.

This formation (Sheet 132*) overlies the Carboniferous (?) limestone, and is extensively developed on the north-western side of the Ord; the Mount Elder Range, on the opposite side, being an outlier of less extent. The prevailing strata consist of white sandstone in horizontal beds, giving rise to tablelands (often denuded to mere fragments) bounded by steep escarpments three or four hundred feet in height. Intervening between these tablelands are extensive sandy "downs" resulting from the degradation of the sandstone. A large area of these "well-grassed plains" has been mapped by Hardman as "Recent."

Naturally no one would dream of boring for artesian water on the fragmentary tablelands; such operations, if attempted, would be confined to the "downs." In the event of the latter being pierced by a bore, the Carboniferous (?) limestone formation would certainly be met with in a few hundreds of feet at the utmost, and the problem before the borer would be precisely the same as that confronting a borer in the limestone formation (*See* previous section No. 6.)

(8.) Flora Valley Carboniferous Sandstone Area.

It is probable that in the low country, anywhere between Gullana Hill and Mount Timperley, artesian water may be met with at no great depth, either in the Carboniferous sandstone itself or in the underlying Devonian rocks.

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* Lands Department Lithographs, 1904.

(9.) The Carboniferous (?) Limestone Area between the Rough and Barker Ranges.

This large area, trending from south-east to north-west includes the Rough, Hull, Geikie, and Napier Ranges, and a portion of the Oscar Range (Sheets 130, 129, and 134*). The formation is composed, so far as my observations went, almost exclusively of limestone, with partings of shale. The strata dip to the south-west, at steep angles, away from the granite of the Lower Louisa Valley and the slatey and schistose metamorphic rocks of the ranges to the north-west upon which they rest unconformably. On reaching the plains, the dip becomes less and less steep, and the strata pass beneath the Carboniferous sandstone series.

The country is fairly well supplied with surface water except, perhaps, at the south-eastern extremity, where it attains a breadth of 30 miles, and even there the Fitzroy and Margaret Rivers provide long well-watered frontages. Back from the frontages, however, prolonged droughts such as the one that had barely come to an end when I passed through, give rise to heartrending distress.

I can only repeat what has been already said in dealing with the Limestone Area between the junction of the Negri and Ord Rivers and the head of the Turner (Section 6), that the success of bores in limestone country is a matter of luck, depending on the chances of striking a subterranean water-bearing channel. One such channel, it may be pointed out, is known in the district now under consideration. Near the north-west end of the Oscar Range a creek disappears underground, and has been followed by my informant until it re-emerges half a mile lower. It is certain that, either in such channels or between the limestone and the underlying metamorphic rocks, there must be enormous quantities of water, derived from the drainage of the south-western slope of the Metamorphic ranges. Several springs arise in the limestone near Oscar Range Station.

(10.) The Carboniferous Sandstone Area south-west of the Oscar and Napier Ranges.

This area is mainly drained by the Fitzroy and Lennard Rivers. Partly from my own traverse on the way to Derby and partly from Hardman's mapping (the " Pindan " foundation being eliminated), I have coloured with confidence, as included in it, over 12,000 square miles. The whole of this enormous area, with the exception of a number of tablelands, there is good reason to believe, is capable of furnishing artesian water.

The strata, chiefly sandstone and shales, dip to the south-west, where they succeed the limestone on the flanks of the Rough, the Oscar, and the Napier Ranges. In passing to the south-west, however, they soon become to all intents and purposes horizontal, and are thus, provided the basal beds of the formation crop out at sufficiently high altitudes, favourably disposed to the existence of artesian water. There is little doubt that the outcrop of the basal bed is high enough. From opposite the Fitzroy telegraph station to opposite the north-west end of the Oscar Range, the elevation of the junction line between sandstone and limestone varies from 500 to 600 feet above sea level, while (except for the tablelands) the general level of the district under consideration can seldom rise above 300 feet.

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* Lands Department Lithographs, 1904.

From Derby to the Fitzroy telegraph station, travellers usually take the circuitous road up the right bank of the Fitzroy, rather than that by the telegraph line, which is nearly direct. On the latter road, there is, in ordinary seasons, a dry stage from the 40 mile to the 92-mile post. When I was travelling in the reverse direction, I was able to follow the telegraph line most of the way, a recent fall of rain having put water in the 57-mile Creek and reduced the dry stage of 52-mile to two stages of 25 and 27 miles. Between the two roads, and south of the Fitzroy, there are broad tracts of country, far removed from water frontages, where abundant grass is useless to stock because of the want of water. In such localities, there is no doubt that artesian water would be of great value, and would immensely increase the cattle-carrying capacity of the pastoral holdings.

It may be well, at this stage, to record such information as has been collected with reference to springs and wells in this region.

Springs.

Probably the most important of all is the spring south-east of Mount Wynne (Sheet 129*), which has an estimated flow of 250,000 gallons per 24 hours.

About six miles south-east of the Lower Liverynga, a mud spring is met with. About two miles farther south, five springs break out on a line running north-west and south-east. These springs discharge not only sand but also fishes, which are said to be sightless. A pipe having been driven into one of the springs, the water rose 3½ feet above the ground.

Eudyella Springs are on the left bank of the Fitzroy, south of Lower Liverynga Station. (Sheet 135*).

Some springs, about nine miles south-west of the station, give out a stream strong enough to " run " Margaret Creek for six miles.

There are also springs of some importance about 15 miles south of Upper Liverynga, between the Fitzroy River and Mount Arthur. (Sheet 128*)

The above information is given on the authority of Mr. Percival Rose, general manager for the Kimberley Pastoral Company.

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* Lands Department Lithographs, 1904.

Wells.

On account of the long dry stage on the telegraph line which has already been referred to, travellers from east to west have to leave the line at Limestone Creek (92 miles from Derby) and make for the site of the old police station on the Lennard—a distance of 30 miles between water and water. A Government well, east of Mount North and north of Mount Percy, breaks up the 30 mile stage into stages of 18 and 12 miles. Beyond the fact that the well has water in it, I was unable to learn any particulars. (Sheet 134*).

A well, 60 feet in depth, at the Lennard Station has "a little" fresh water.

A shaft was sunk on the telegraph line, at 71 miles 26 chains, to a depth of 100 feet, without meeting any water. So far as I could see the shaft (which had partly fallen in), there was dark carbonaceous shale beneath ten feet of cemented gravel (Hardman's "pindan" formation).

Two series of wells have been made on Balmaningarra run, and for the information regarding these I am indebted to Mr. J. L. Hutton, the manager. The approximate position of the wells is given on Sheets 134 and 135*.

The first series was sunk by Wilson and Buck.

No. 1 well (Sheet 145*) on Mr. M. C. Davies' Block 330/98, 16 miles east of Derby, is 102½ feet deep, and has eight feet of water. The last rock turned up by the sinkers, as I saw it in passing, was a very soft, crumbling white grit, well fitted for the retention or passage of water.

Wells Nos. 2 and 4 (Sheet 134*) are about four miles south of the telegraph line, No. 2 south of the 45, and No. 4 south of the 55-mile post, and No. 3 is in an intermediate position.

No. 2, 39½ feet deep, with 13 feet 3 inches of water.

No. 3, 61 feet deep. Water in bore at 36½ feet.

No. 4, 60 feet 10 inches deep. Water struck in bore at 53 feet, rose to 45 feet 10 inches.

The second series was sunk by Foley and Hillier (Sheet 134*).

Nos. 1 and 2, on the dividing line between Blocks 248/98 and 249/98, were both 15½ feet in depth, and met with salt water. A report by the Government Analyst gives the proportion of sodium chloride as 1580 grains per gallon in No. 1 and 577½ grains in No. 2.

No. 3 well, about three miles east of No. 2, struck comparatively fresh water at 35 feet. It stands 19 feet deep, and, according to analysis, has 288¾ grains of sodium chloride per gallon.

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* Lands Department Lithographs, 1904.

No. 4, about a mile west of the station, is 28½ feet deep and has three feet of fresh water. The analysis gives only 79.3 grains of sodium chloride per gallon.

No. 5, three miles north-east of station, has a depth of 42 feet. Fresh water was met with at 28 feet and rose 12 inches.

Upper Liveryunga Bores.

Two bores on this run, as I am informed by Mr. Rose, have actually struck artesian water at shallow depths.

One, about three miles north-east of Mount Wynne, has a flow of 7,000 gallons per 24 hours. I could not ascertain the precise depth of the bore (Sheet 134*).

The other, about three miles north-east of the station (Sheet 135*), is 70 feet deep, and discharges 1,500 gallons per 24 hours. A 1½-in. pipe having been cemented in, the water rises 12 inches above the surface.

Yeeda Wells.

The information regarding these wells is given on the authority of Mr. T. Galbraith, the manager. Their position (east of the Yeeda River) is marked on Sheet 135*.

No. 1, 40 feet deep; in sandstone; seven feet of water.

No. 2, 35 feet deep; in sandstone; seven feet of water, which comes from a hole in bottom, and *pulsates*.

No. 3, 28 feet deep; in sandstone and ironstone; five feet of water.

No. 4, 80 feet deep; in sandstone; eight feet of water; supply too large to be baled out.

No. 5, 95 feet deep; in sandstone; 20 feet of water.

No. 6, in progress.

Wells between Meda Station and Derby.

A well was sunk by the Road Board, about 1½ miles west of Wilson and Buck's No. 1 well, to a depth of 70 feet, without success. (Sheet 135*).

At Gooda Gooda, on the edge of the swamp, about seven miles east of Derby, a well (Sheet 135*), just above high water mark, has a copious supply of fresh water at a depth of about 12 feet.

Mayalli Well, about three miles south-east of Derby, is 30 feet deep, and has about six feet of somewhat brackish "stock" water. It has a windmill and a hot air pump, a tank of a capacity of 25,000 gallons, and troughing. As regards the supply, I was informed that it has watered 1,000 head of cattle continuously for a week. Reckoning 10 gallons of water per head daily, this would amount in a week to 70,000 gallons.

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* Lands Department Lithographs, 1904.

Wells in Derby.

These wells, which are too close together to be shown on the 300 chain map, are located on the six chain plan of the "Townsite of Derby," 1896.

The Town and Jetty Supply Well is in the north-west corner of the Hamersley Square. I visited it and obtained from Mr. Armitage, of the Water Supply Department, the following particulars :—

> The water is pumped by a windmill to elevated tanks and delivered by pipes to the town and jetty. A gas engine is about to be installed, and a new reticulation has been commenced. A shaft was first sunk to the depth of 35 feet, the section showing three feet of sand, four feet of gravel, and 28 feet of "rock." Water was struck in "pipe-clay" (decomposed shale), in a bore which was carried down to 50 feet. The water rose in the bore, which, however, was plugged up, and the shaft was sunk to a total depth of 48 feet. The water then rose to 20 feet from the surface, a level which it has since maintained.
>
> The supply has, at times, not been equal to the demand, but this is attributed not to the well but to the windmill.

The private wells in the town were gauged during my stay in Derby, with the guidance and assistance of Mr. McGovern, one of the oldest and most enterprising residents.

In Allotment 42.—Well 26 ft. 8 ins. deep. Bored to 52ft. 8ins. through "pipe-clay" to water-bearing bed, when the water rose in an hour to 15 feet from surface. Water now standing 15ft. 3ins. from surface.

In Allotment 43.—Depth 31 feet ; 16 feet 3 inches of water standing.

In Allotment 84.—Depth, 21 feet 4 inches. Water now standing 18½ feet from surface.

In Allotment 45.—Depth, 31 feet 9 inches. Water now standing 14 feet 4 inches from surface.

In Allotment 76.—Depth, 32 feet 4 inches. Water now standing 17 feet 3 inches from surface.

In Chinese Garden.—(Allotment 72) (?).—Depth, 39 feet 9 inches. Water now standing 25 feet 1 inch from surface.

In Forrest Street, opposite Allotment No. 1.—Shallow ; surface soak only.

In Delaware Street, opposite Allotment No. 54 :—Shallow ; surface soak only.

Observations on Wells and Bores in Area 9.

The sub-artesian character of a large number of the wells is very significant. That water, when met with in a well or bore, should rise for some distance, even if it comes short of the surface, proves that the water is conveyed in a stratum of rock which rises to the surface at an altitude at least as high as that to which it rises in the well or bore when the impervious bed overlying it has been pierced.

The sub-artesian water would have been artesian water if the surface had been lower. If we take, for instance, a site 100 feet above sea-level, and, on boring to 50 feet, strike water which rises to 40 feet, or to 90 feet above sea-level, we have missed artesian water by only ten feet. In other words, if the surface had been 90 feet or say 89 feet, above sea-level, we should have had an artesian supply. This shows the necessity of *selecting low sites* for bores, except, of course, in areas where the underground water-level is already well known. In the hypothetical case we have used as an illustration, the water-bearing stratum must rise to the surface at a higher level than the surface of the bore, but had the bore been carried deeper into the same formation, it is highly probable that further water-bearing strata rising to more distant and more elevated outcrops would have been met with, triumphantly realising the desired object, viz. : artesian water.

It cannot be too strongly insisted upon that two artesian bores (at Liverynga) have already been sunk in the district. Although these bores are on a small scale, they, and numerous sub-artesian wells and bores, prove that artesian water is no longer a matter of theory.

The delay of my steamer for a few hours at Broome enabled me to visit, with Mr. Armitage, the town and jetty supply wells in that township. They are situated near the English Church, at the foot of a ridge of blown sand, and about 44 feet above sea-level.

The three wells from which the supply is pumped for the town and jetty are all between 10 and 11 feet in depth, and yield a copious supply of fresh water. One of them, however, was sunk a foot farther and got into salt water.

In the same enclosure, a bore is in progress in search of artesian water. The following notes on samples of strata from various depths may be of interest, as showing the nature of the rocks met with in nearly 500 feet of boring through Carboniferous rocks—the same formation as that at Derby (Area 9):—

Fine red sand, from surface to	30 feet
Red sandstone, thence to	46 „
Fine white argillaceous and siliceous sandstone, thence to	68 „
Fine siliceous sandstone, purely coherent, thence to	80 „
Fine siliceous sandstone, thence to	88 „
Fine siliceous sandstone, less coherent, thence to	103 „
Fine siliceous sand with mica, thence to	210 „
Unconsolidated siliceous grit (grains size of No. 1 shot), with salt water, thence to	220 „
Fine white siliceous sand (core), thence to	282 „
Fine red siliceous sand, thence to	290 „
Coarse, friable siliceous, felspathic grit (grains size of swan shot) with salt water, thence to	310 „
Fine white siliceous sand (core), thence to	340 „
Unconsolidated siliceous grit (grains size of No. 1 shot) with salt water (core), thence to	345 „
Fine white siliceous and micaceous sand (core), thence to	388 „
Fine yellow siliceous grit, thence to	445 „
Fine siliceous sand, thence to	451 „
Grey sandstone, thence to	466 „
Coarse grit or fine conglomerate, with salt water, thence to	468 „
Coarse siliceous grit, thence to	478 „

Salt water was standing at 20 feet from the surface.

A record of the strata passed through in the bore at Pelican Hill, Carnarvon, will be found in the Annual Reports of the Geological Survey for the years 1902 and 1903. The bore was carried to a depth of 3,011 feet. The result is thus summed up by Mr. Gibb Maitland:—"At a depth of 2,611 feet the supply of artesian water yielded 300,000 gallons per diem, and at 3,011 feet the supply was 520,000 gallons." When it is remembered that the strata at Carnarvon are Carboniferous, that is, of the same age as those of Derby, there is the less reason to fear that the latter will prove too hard or too close in grain to carry water. As the strata in the Derby district, so far as the evidence goes, present the remaining conditions necessary to the presence of artesian water, there need be no hesitation in making the experiment.

Concluding Remarks.

My special thanks are due to Mr. Armitage, of the Water Supply Department, for much valuable information; to Dr. Maloney, Resident Magistrate, Wyndham, and Dr. MacQueen, Resident Magistrate, Derby, for placing many facilities at my disposal; to Mr. W. E. Cooke, Government Astronomer, for a careful reduction of my aneroid readings; and to Mr. J. J. Butler, of Wyndham, who supplied horses and saw me successfully through the many difficulties placed in the way by a drought of unprecedented severity.

In the matter of aneroid altitudes, it may be said that the aneroid I carried appears to have, as a rule, given too high results. For example, my reading at Hall's Creek was 1,400 feet, whereas the correct altitude is more likely to be 1,225 feet, the average of numerous barometrical readings. In spite of this, however, my readings (allowing for atmospheric disturbances) are at least approximately proportional, so that, in speaking of the comparative altitudes of different localities, the validity of the argument is not affected by the error.

In the preceding pages the geological sketch may be tedious to many readers, but it was necessary to show the grounds on which I arrived at my conclusions. The subject has by no means been exhausted, although its further discussion had better, perhaps, be reserved for the pages of a geological journal.

In the latter part of the report I have passed in review nine distinct areas (defined on the map) in which, according to my lights, I anticipate more or less success in the search for artesian water, and have discussed each of them on its own merits. However the financial questions involved may be adjusted between the Government and the pastoral lessees, I entertain no doubt that artesian water is destined to play an important part in the future of the pastoral industry of the Kimberley District.

R. LOGAN JACK.

Surrey Chambers, Perth, 27th February, 1906.

APPENDIX.

Itinerary and Notes on Water.

	Sheet of 300 ch. Map.*	Miles.	Notes.
Wyndham to Parry's Lagoon ...	142	15	Permanent water.
Parry's Lagoon to Pear Tree Camp	„	15½	
Pear Tree to "Bend of Ord River" (House Roof Crossing)	„	2½	Permanent water above crossing.
Pear Tree to Ivanhoe Stud Station	„	17	Well.
Ivanhoe to Emu Springs	„	18	Permanency of water doubtful.
Emu Springs to Torrance & Smith's Well	„	3½	In progress; no water yet at 65ft.
Torrance and Smith's to 8-Mile Well	„	5½	
8-Mile Well to Cockatoo Springs ...	141	8	Permanent water.
Cockatoo Springs to Golden Gate...	„	3	Waterholes were nearly dry, but replenished by recent rain.
Golden Gate to Pickle Bottle Creek	„	8	Permanency of water doubtful.
Pickle Bottle Creek to Hicks' Creek	„	11	Dry.
Hicks' Creek to Argyle Downs Station	„	11	
(Argyle Downs to Stockade Creek, Soda Springs and back, 10 miles)	...	...	Permanent water.
Argyle Downs to Behn River, last crossing	„	25	Permanent water.
(Behn River to Rosewood Downs Station, Northern Territory, and back, 20 miles)	...	...	Well and water in Stockade Creek.
Behn River to Sugar Springs (bores)	„	4	Permanent water.
Sugar Springs to Argyle Police Station (locally "Wild Dog")	„	12	Permanent water.
Argyle Police Station to Spring Creek (near Spring Vale Station)	„	6	Permanency of water doubtful.
Spring Creek to 14-Mile Creek ...	„	7	Permanent water.
14-Mile Creek to 9-Mile Creek ...	„	7	Water from recent rain.
9-Mile Creek to Negri River ...	132	9	Permanent water.
Negri River to Ord River, Camp 12	„	5	Permanent water.
(Camp 12 to Texas Station, 2 miles; well to Salt Springs in Ord River, 2 miles and back—8 miles)	...	...	Permanent water.
Camp 12 to White Mountain Creek	„	14	Water doubtful.
White Mountain Creek to Kelly's Creek	„	3	Water from recent rain.
Kelly's Creek to Ord River Station (Forrest Creek)	132	7	Wells.
Ord River Station to Gully ...	„	8	Water from recent rain.
Gully to "The Brook," tributary of Linacres River	„	7	Permanent water.

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* Lands Department Lithographs, 1904.

ITINERARY AND NOTES ON WATER—*continued.*

	Sheet of 300 ch. Map.*	Miles.	Notes.
"The Brook" to Nicholson River, first crossing	142	6	Dry.
First to second crossing of Nicholson	„	5	Dry.
Second crossing to Nicholson hut ...	„	6	Permanent water.
Nicholson hut to last crossing of Nicholson	„	5	Permanent water.
Nicholson River to Gap in Hardman Range	„	15	
Hardman Range to Turner River	„	2	Permanent water for digging.
Down Turner River to Crossing ...	„	1½	
Turner River to Gap in Basalt Range	„	4½	
Gap to Springs	„	2	Permanent water (?)
Springs to Coogeebrin ruined station, Elvire River	„	6	Permanent water.
Coogeebrin to Camel Creek Yard ...	„	8	Permanency of water doubtful.
Camel Creek Yard to Camp 18 ...	131	7	Dry.
Camp 18 to J 48, Elvire River ...	„	8	Permanent water.
J 48 to Flora Valley Station, Elvire River	„	18	Wells.
Flora Valley to Mud Springs ...	„	15	Permanent water.
Mud Springs to Palm Springs, near Black Elvire River	„	3	Permanent water.
Palm Springs to Hall's Creek Telegraph Station	„	20	Wells.
Telegraph Station to Head of Hall's Creek, Camp 22	130	5	No permanent water.
Camp 22 to Rockhole Pool (Langley's Sheep Station)	„	12	Permanent water.
Rockhole Pool to Claypan	„	10	Water from recent rain.
Claypan to Tailers' Camp	„	2	Water from recent rain.
Tailers' Camp to Laura Billabong	„	4	Water from recent rain.
Laura Billabong to Claypans at 267-mile Telegraph Pole	„	12	Water from recent rain.
Claypans to Margaret River ...	„	7	Dry; water from recent rain.
Margaret River to Soda Springs ...	„	12	No water—Water in bed of creek (dig) about 251¾ telegraph mileage.
Soda Springs to Gully, between 245 and 250 miles	„	5	Dry.
Gully to Dead Horse Creek, at 240 miles	„	8	Water for digging.
Dead Horse Creek to Spinifex Flat—Camp No. 27, near 233 Telegraph Mile Pole	„	9	Dry.
Camp 27 to Margaret River ...	„	15	Nearly dry—water for digging

* Lands Department Lithographs, 1904.

ITINERARY AND NOTES ON WATER—*continued.*

	Sheet of 300 ch. Map. *	Miles.	Notes.
Margaret River to Spring Creek	130	2	Water from recent rains.
Spring Creek to Camp 28	”	1	Dry.
Camp 28 to Pont's Creek ("F 140" Creek)	”	2	Water up creek.
Pont's Creek to Morgan's Grave ... (Res. 1580)	”	15	Water.
Morgan's Grave to Mount Fairbairn	”	2	
Mount Fairbairn to Camp 29, near Telegraph Pole 198 mile	”	2	Dry.
Camp 29 to Rockhole on Louisa River	”	8	Dig for water in sand.
Rockhole to Louisa Crossing ...	”	1½	
Louisa Crossing to Camp 30 on Margaret River, near Black Rock	”	7½	Permanent water in river.
Camp 30 to Minnie Pool	”	6	Permanent water.
Minnie Pool to Camp 31 on Margaret River, near Mt. Pierre	129	12	Permanent water.
Camp 31 to McDonald's Crossing of Margaret River	”	8	Permanent water.
McDonald's Crossing to Fitzroy Telegraph Station	”	14	Well.
Fitzroy Telegraph Station to Fitzroy Crossing	”	6	Permanent water.
Fitzroy Crossing to Brooking Creek Hotel	”	1	Permanent water.
Hotel to Oscar Range Station ...	134	14	Permanent water.
Oscar Range Station to "6-mile Well"	”	8	Water.
"6-mile Well" to "120-mile Creek"	”	5	Permanent water.
120-mile Creek to 117-mile Pool ...	”	3	Water from recent rain.
117-mile Pool to 107-mile Creek ...	”	10	Running water—recent rain
107-mile Creek to 100-mile Fence...	”	7	Pool from recent rain.
100-mile Fence to Limestone Creek	”	8	Water scarce; said to be four or five more miles up creek.
Limestone Creek (92-mile) to 67-mile Creek	”	25	Running water from recent rain, but usually dry. Tanks erected for telegraph repairers. NOTE.—There is usually no water between Limestone Creek and the "Corner Billabong" (May River). Travellers in ordinary weather must leave the telegraph line at Limestone Creek, and go *via* Mt. Percy and Mt. North (Government Well between) the Lennard River, and Balmaningarra Station, rejoining the telegraph line about the 36 mile pole. Distance, approx. 72 miles.

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* Lands Department Lithographs, 1904.

ITINERARY AND NOTES ON WATER—*continued.*

	Sheet of 300 ch. Map.*	Miles.	Notes.
67-mile Creek to 56-mile Pole ...	"	11	Water from recent rain.
56-mile Pole, North, across Plain (no track) to Creek outside of Balmaningarra Sheep Paddock	"	6	Permanent water.
Creek to Balmaningarra Station ...	"	8	Permanent water.
Balmaningarra Station to Yard on May River	"	4	Running from recent rain.
Yard to "Corner Billabong" ...	135	5	Permanent water.
"Corner Billabong" to 36-mile Telegraph Pole	"	8	Water from recent rain.
36-mile Pole to Emanuel's Yard ...	"	3	
Yard to Meda Station	"	9	Permanent water.
Meda to Open Well	"	10	
Well to Gooda Gooda	"	10	Well.
Gooda Gooda to Derby	"	7	Wells.
		714	

* Lands Department Lithographs, 1904.

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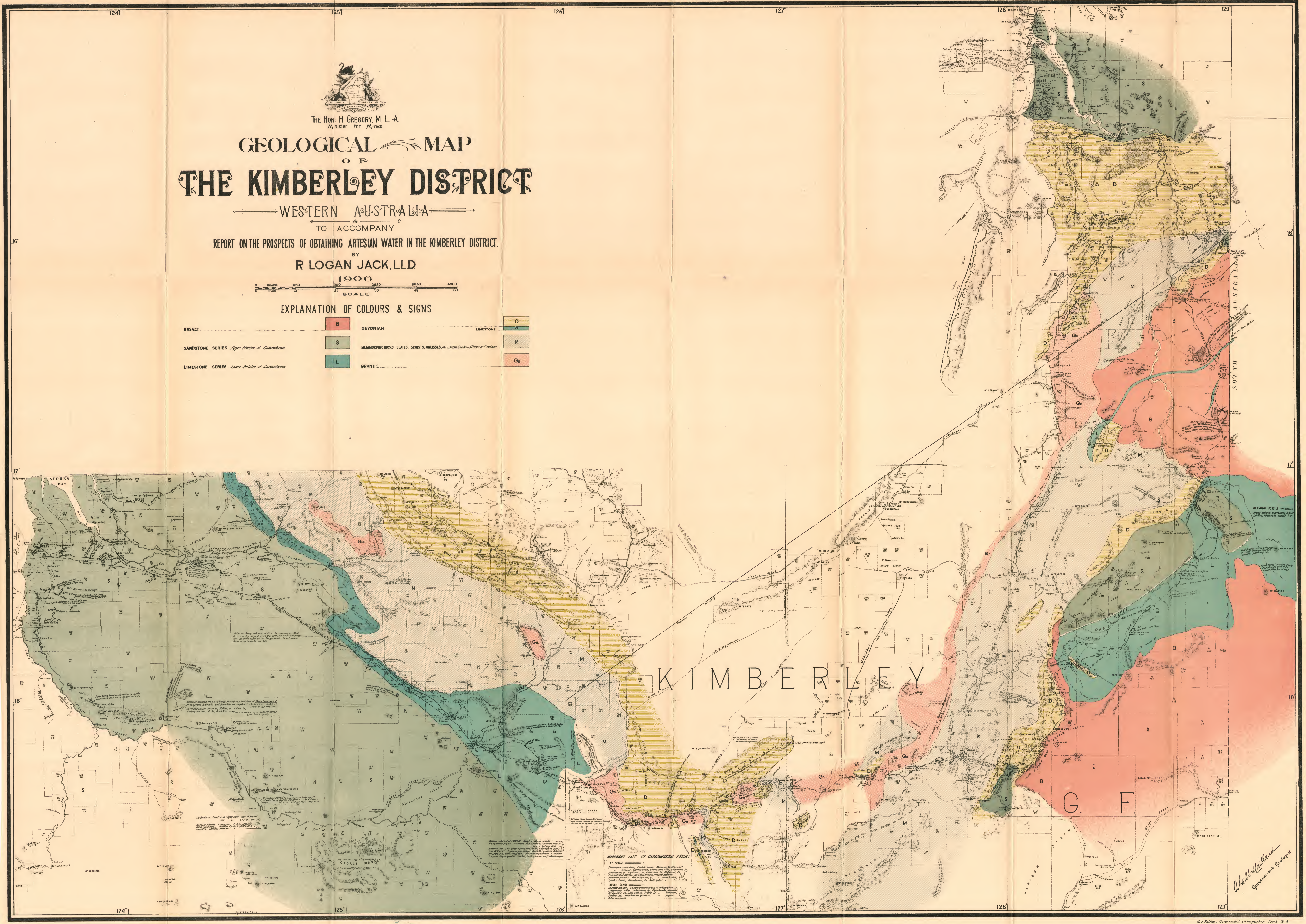

THE HON: H. GREGORY, M. L. A.
Minister for Mines.

GEOLOGICAL MAP OF THE KIMBERLEY DISTRICT

WESTERN AUSTRALIA

TO ACCOMPANY
REPORT ON THE PROSPECTS OF OBTAINING ARTESIAN WATER IN THE KIMBERLEY DISTRICT.
BY
R. LOGAN JACK, LL.D.
1906

SCALE
CHAINS 0 960 1920 2880 3840 4800
MILES 0 12 24 36 48 60

EXPLANATION OF COLOURS & SIGNS

BASALT	B
SANDSTONE SERIES *Upper Division of Carboniferous*	S
LIMESTONE SERIES *Lower Division of Carboniferous*	L
DEVONIAN	D
LIMESTONE	d
METAMORPHIC ROCKS: SLATES, SCHISTS, GNEISSES, &c *Silurian Cambro-Silurian or Cambrian.*	M
GRANITE	Gn

A Gibb Maitland
Government Geologist

H. J Pether. Government Lithographer. Perth. W. A.

1907.

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 26.

MISCELLANEOUS REPORTS,

Nos. 1—8.

Issued under the authority of the Hon. H. Gregory, M.L.A.,
Minister for Mines.

WTIH 6 GEOLOGICAL MAPS AND 14 FIGURES.

PERTH:
BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.
1907.

PREFATORY NOTE.

This Bulletin includes a series of miscellaneous reports by various members of the staff, which in themselves are not sufficiently large to warrant issue as separate publications.

These reports have not been published in the official records of the State (though most of them appeared in the local press) and the issue of them in a collective form will, it is hoped, serve to make known the varied mineral and allied resources of Western Australia.

A. GIBB MAITLAND,
Government Geologist.

Geological Survey Office,
Perth, 18th March, 1907.

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1.—Possibility of the Occurrence of Artesian Water in the Northampton and Geraldine Districts.

(*With a Map.*)

The consideration of the question as to whether the pastoral lands lying "beyond Geraldton, North of Northampton" are capable of yielding artesian water is very much a matter of geological investigation and mapping.

It is not clear to what special portion of the Murchison District the motion brought forward in Parliament, on the 6th of December last, refers. This motion reads :—

> Whether in view of the fact that the carrying capacity of the great wool-producing centre beyond Geraldine, north of Northampton, would be very much increased if there was an ample and certain water supply, the Government would be prepared at an early date to bore in that district for the purpose of testing whether artesian water existed there or not.

In the year 1897 a traverse was made of the country between Northampton and Peak Hill (*a*), and an examination, in more or less detail, was made of the valley of the Murchison River as far as the big bend at Bompas Hill. Later on, in the year 1900, I traversed the country between Cue and Carnarvon, in connection with the question of artesian water (*b*), and in the early part of 1901 returned from Carnarvon to Northampton along the telegraph line.

These traverses, coupled with the information contained in the different official reports by my predecessors, together with the records of the bores put down during the last few years, afford ample data for dealing with the broader aspects of the question without a special visit to the district being necessary.

Since the date of my report of December 17th, 1896 (*c*), some boring has been carried out in the Champion Bay District, having the search for artesian water for its object. Two of these bores, viz., Dongara (*d*) and Yardarino (*e*), have been successful in obtaining overflowing supplies; the Geraldton Racecourse Bore (*f*), a sub-artesian supply, whilst the Geraldton Station Yard Bore (*g*), having reached bedrock at 420ft., obtained no water.

(*a*) Annual Progress Report of the Geological Survey for the year, 1897. Perth: By Authority, 1898, pp. 14-19.

(*b*) Annual Progress Report of the Geological Survey for the year 1900. Perth: By Authority, 1901, pp. 26-28.

(*c*) Annual Progress Report of the Geological Survey for the year 1896. *Vide* Annual Report Department of Mines for the year 1896. Perth: By Authority, 1897, p. 28.

(*d*) The Mineral Wealth of Western Australia. Geological Survey Bulletin No. 4. Perth: By Authority, 1900, pp. 105-106.

(*e*) Annual Progress Report of the Geological Survey for the year 1901. Perth: By Authority, 1902, pp. 13-14.

(*f*) The Mineral Wealth of Western Australia. Geological Survey Bulletin No. 4. Perth: By Authority, 1900, pp. 140-141.

(*g*) Loc. Cit. p. 139.

The bore at Pelican Hill (*a*), Carnarvon, which had been carried down to a depth of 3,011ft., obtained an overflowing supply of water at the rate of 520,000 gallons per diem. The record of this bore shows in descending order :—About 150ft. of newer or post-tertiary strata; about 1,211ft. of mesozoic (and possibly cretaceous) rocks ; and about 1,650ft. of carboniferous rocks ; the base of the latter formation, however, was not reached.

The important point in this bore is the fact that the main artesian supply is drawn from the bed of sandstone, 448ft. in thickness, which forms the lowest bed of the carboniferous series penetrated.

These strata cross the Gascoyne River and extend without any interruption southwards to the valley of the Wooramel somewhere between Innouendy and Bilung Pools (*b*). At the former place granitic rocks prevail, whilst in the vicinity of the latter, sandstones, shales, and conglomerates, dipping south-west at a low angle, occupy the country. The pebbles in the conglomerate are of rocks identical with those which form the Coor-de-Wandy, Yalbra, and similar hills.

Near the mouth of the Wooramel River there are, in addition to the coastal limestone, fossiliferous tertiary rocks, and the mesozoic beds, from beneath which the carboniferous strata, described in the last paragraph, emerge and occupy the surface of the upper portion of its course.

Little or no geological mapping has been carried out between Coor-de-Wandy on the Upper Wooramel and Mount Narryer on the Upper Murchison, but between the latter hill and Tilly Gully (*b*), the older crystalline rocks give place to the almost horizontal sedimentary beds, which make such a prominent feature in the Woodrarrung Range (*c*), and which, there are very strong geological reasons for believing, represent the southward extension of the carboniferous rocks of the Wooramel.

In the valley of the Murchison River, somewhere below Bompas Hill, is a fairly large development of sedimentary beds. In the vicinity of the 14-mile crossing, some distance above the Geraldine Mine, and 80ft. by aneroid above it, is an exposure of what appears to be an older series of strata than that comprising the Woodrarrung Range. The lowest bed in the section is conglomerate and breccia, composed of angular fragments of quasi-vitreous quartzite, dipping to the east ; the base of the conglomerate is not visible. A peculiar feature of some of the pebbles is that they are covered with slicken-sides, which, however, have no prevailing direction. A few yards lower down the river is a bed of quasi-vitreous sandstone overlaid by beds of cross-bedded sandstone and fine conglomer-

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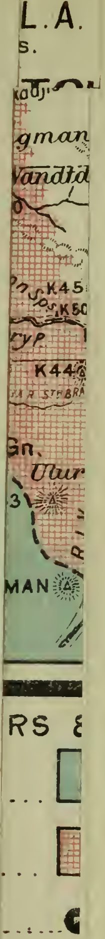
(*a*) Annual Progress Report of the Geological Survey for the year 1902. Perth: By Authority, 1903, pp. 23-24: also Annual Progress Report of the Geological Survey for the year 1903. Perth: By Authority, 1904, p. 34.

(*b*) Lands Department Lithograph, 2m.

(*c*) Lands Department Lithograph 6m.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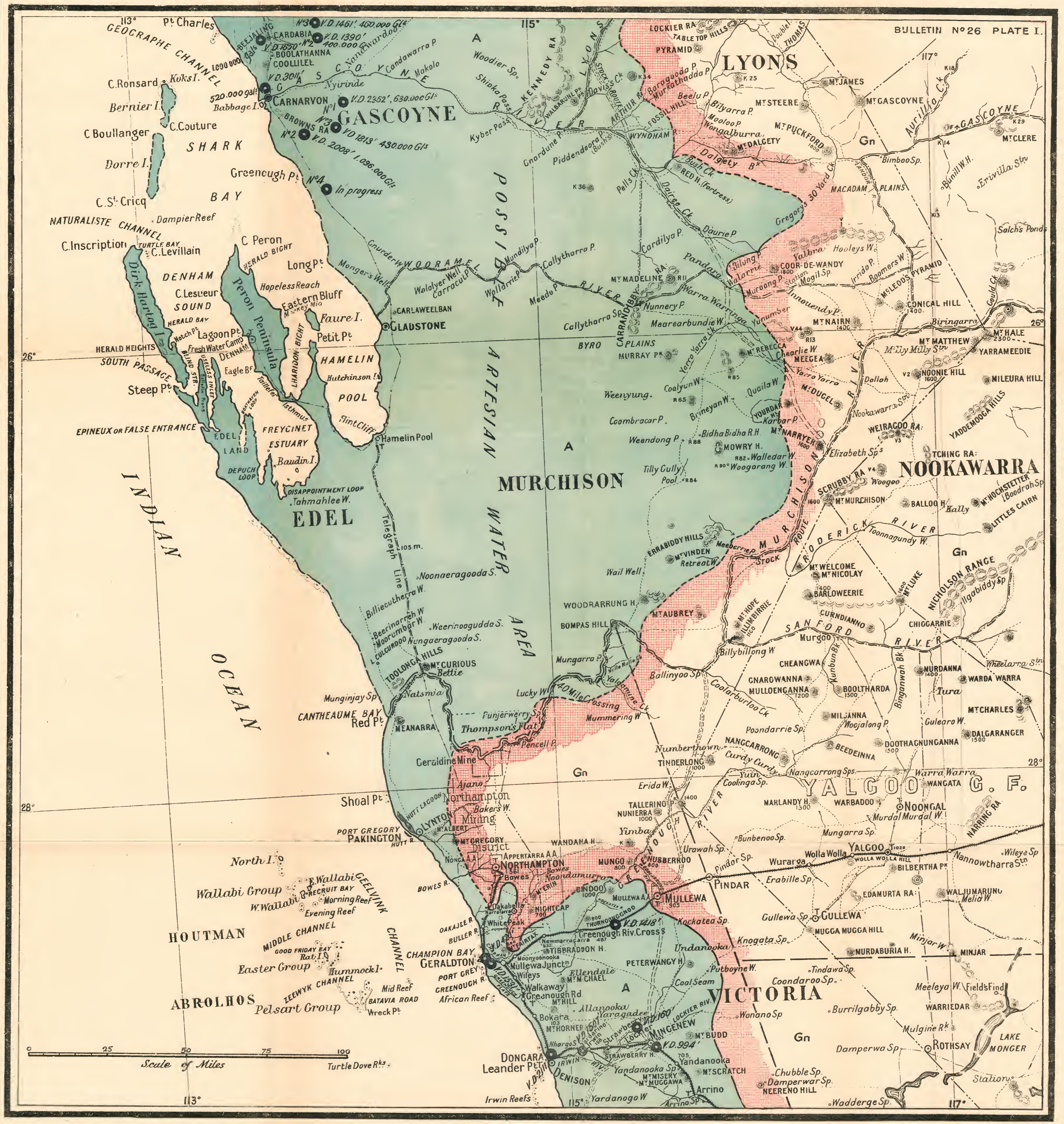
The Hon H. Gregory M.L.A.
Minister for Mines.

GEOLOGICAL SKETCH MAP
SHEWING

THE POSSIBLE ARTESIAN WATER AREA TO THE NORTH OF NORTHAMPTON

BY
A. Gibb Maitland.
GOVERNMENT GEOLOGIST.
1907



EXPLANATION OF COLOURS & SIGNS

Carboniferous, Mesozoic and Tertiary strata	A	Artesian water bearing in places
Crystalline Schists, Granite, Quartzites &c	Gn.	Non Artesian
Bores	●	

ate, trending north and south, and dipping east at an angle of 20 degrees. One of the sandstone beds has evidently been much faulted, for one of the beds is slickensided to such a degree as to produce surfaces as smooth and polished as plate glass.

Lower down the Murchison the sedimentary beds referred to in the last paragraph give place to the older crystalline rocks (gneiss, etc., with greenstone dykes), which occupy the country to a point on the river in the vicinity of the peg W. 1., on the boundary of Location 66/1135 (*a*).

Near this point, which is about twenty miles east of the sea coast, the Murchison River enters a narrow gorge, flanked by vertical walls of sandstone and grit. The junction between these sandstones and the older gneissic rocks, as can be seen by a section on the north bank of the river, is a fault dipping to the west. This sedimentary formation occupies the whole of the Murchison Valley as far as its mouth in Gantheaume Bay.

A traverse from Carnarvon to Northampton, *via* Gladstone, Hamelin Pool, and the Murchison River, near Mount Curious, in 1901 showed the staple formation to consist of sandstones, grits, etc., together with their decomposition products, indicating the continuity of the same geological formations seen outcropping on the high ground along the upper portions of the valleys of the Gascoyne, the Wooramel, and the Murchison Rivers.

No observations as to the actual discharge of the Wooramel and the Murchison Rivers would appear to have been made, so that no estimate of the amount of water absorbed by the sedimentary beds can be arrived at. From the available records, it seems that the rainfall of the district is fair, and that, after due allowance has been made for evaporation and run-off, a good deal of the rainfall must disappear underground, and be capable of being reached by wells or bore holes.

Having due regard to all the prevailing geological conditions of the country to which previous reference has been made, it may be said that, on the whole, the area occupied by the carboniferous and newer strata is favourable as regards the possibility of the occurrence of artesian water, whilst so far as can be judged by the present evidence, the chances of obtaining overflowing supplies is greatest on the lower-lying ground near the coast.

To the eastward of the boundary between the carboniferous and newer strata, no hope of obtaining a supply of artesian water exists.

A Geological Sketch Map, Plate I., accompanies this report.

A. GIBB MAITLAND.

(*a*) Lands Department Lithograph, C. 71.

2.—On the country between the Ashburton and Minilya Rivers with a view to determining the northwards extension of the Gascoyne Artesian area.

(*With a Map.*)

In the immediate vicinity of Onslow, the country is of an estuarine character, consisting of salt marshes and mangrove swamps with blown sand ridges containing large quantities of oyster and other recent shells.

For its water supply the town is dependent upon a number of shallow wells sunk in the sand, the water in which varies very considerably in quality, whilst the supply is limited, being entirely dependent upon the local rainfall.

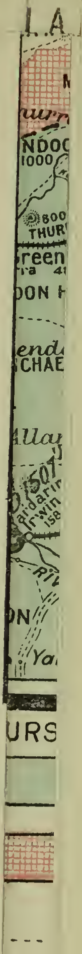
Beneath the sand hills and swamps a heavy blue clay is met with, in the upper portion of which, if water is struck, it is of an extremely bad quality, whilst all attempts to obtain a supply by sinking through it have so far failed. Some years ago a bore was put down by the Government to a depth of 1,729ft., in which the first supply of water was struck at 1,015ft., which trickled over the surface at the rate of 20 to 30 gallons per diem. At a depth of 1,717ft. a further supply was cut which yielded 120 gallons per diem, the hydrostatic pressure being 10.82lbs. per square inch, and hydrostatic head 25ft. above the surface, the water being salt. The bore passed through shale for the greatest proportion of the depth and was discontinued in black shale, locally known as "black Jack."

Following up the Ashburton River in a southerly direction, large alluvial plains stretch east and west as far as the eye can reach, water being either obtained from the pools in the river bed or from wells sunk in the various groups of blown sand hills which here and there break the monotony of the flats.

This class of country extends for a distance of about 50 miles, where it is suddenly terminated by an outcrop of crystalline rocks, which from this point southward present a fairly bold escarpment to the westward.

Between the Ashburton and Yannarie River are large plains of a more or less flooded character, and it is on to these that the last-mentioned river discharges its waters, at a point upon the telegraph line about 65 miles from Onslow, whilst the plains in flood time drain into the salt flats and marshes lying upon the eastern side of Exmouth Gulf.

This plain country extends up the Yannarie as far as Jane Well (C. 29), from which point the country rises rapidly, the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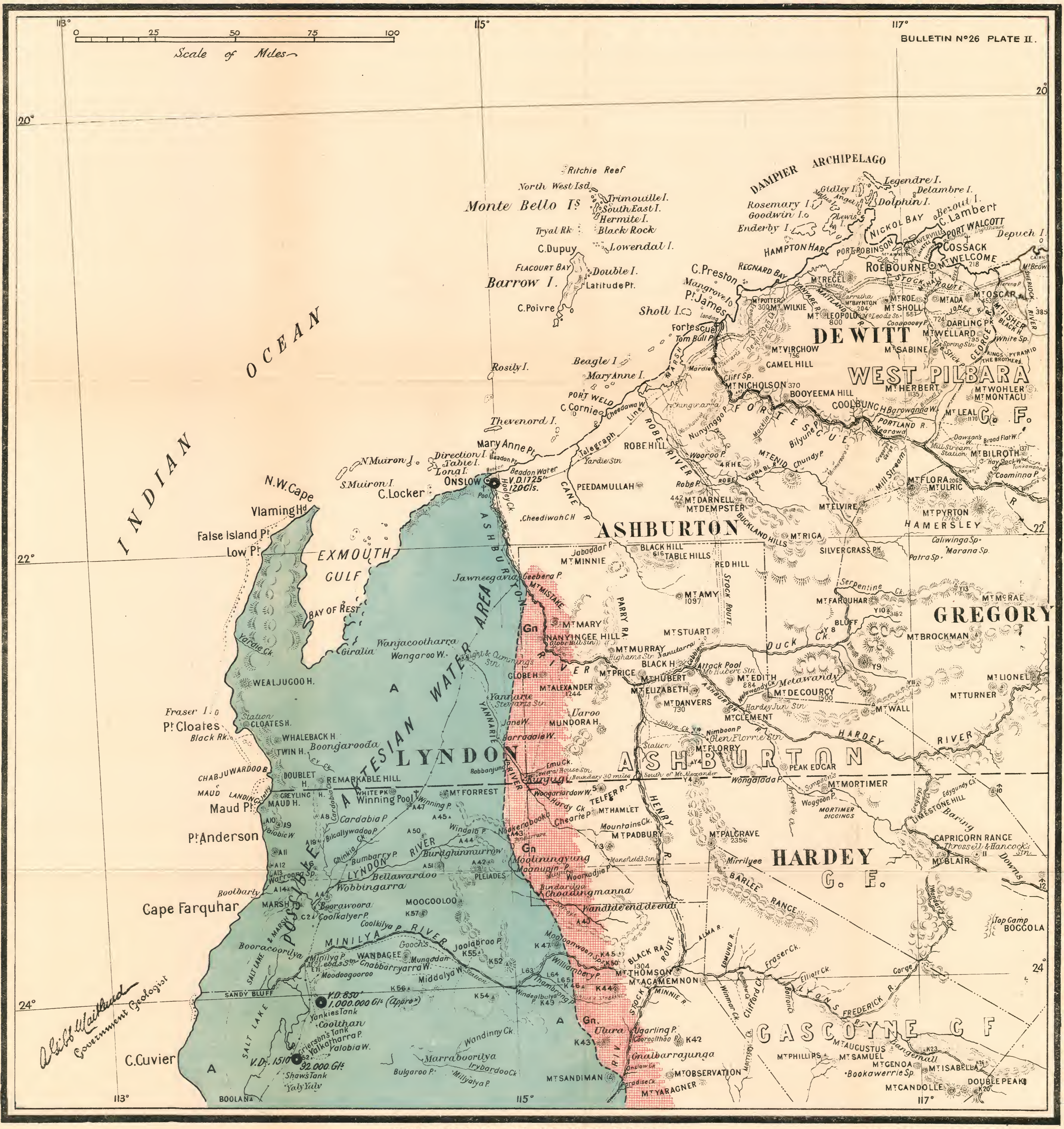
The Hon: H. Gregory M. L. A.
Minister for Mines.

GEOLOGICAL SKETCH MAP
SHEWING
THE POSSIBLE ARTESIAN WATER AREA BETWEEN THE MINYLIA & ASHBURTON RIVS
BY
H. P. Woodward
ASSISTANT GOVERNMENT GEOLOGIST.
1907



EXPLANATION OF COLOURS & SIGNS

H. J. Pether. Government Lithographer. Perth. W. A.

Carboniferous and Younger Rocks .... A *Artesian water bearing in places*

Crystalline Schists, Granite &c .... Gn *Non Artesian*

Bores .... ●

surface being covered by a red sand, with occasional outcrops of limestone.

At Nganyou Pool (C. 26) the crystalline rocks with quartz reefs make their appearance, overlaid by limestone conglomerate, the junction of the two formations following a line slightly to the east of north.

From Wogoola Station (Cameron and Clark's), upon the Yannarie at its junction with Emu Creek, a road runs south-westward to the Winning Telegraph Station, along which the crystalline rocks outcrop for about six miles to be suddenly replaced by shales. At a point seven miles to the westward of the station a well has been sunk in them to a depth of 80 feet, at which depth a good water supply was struck. These shales are highly altered (locally called kaolin) ; this change from the normal dark blue is in all probability due to the leaching subsequent to the oxidation of the pyrites, which often occurs associated with them in considerable quantities. At a point 10 miles west of the station another well has been sunk in the shales to a depth of 162 feet, but so far no supply of water has been struck. In this well some green fossiliferous shales were passed through, but these have now all weathered away and only portions of a cast of an ammonite were obtained from Mr. Cameron.

For the next 10 miles a series of clay pans and sandy flats are crossed, after which low shale hills strewn in patches with much quartz and ironstone rubble are passed over, until the telegraph line is reached.

To the northward of the Telegraph Station at Winning and to the westward of the line are a series of altered shale hills, which present a cliff-like face to the eastward, the beds of which have a distinct, although slight dip to the north-eastward.

Between Winning and Towera Station on the Yannarie (Mr. Twitchin's), travelling due east, are a series of low shale hills, of which Mt. Forrest is the highest, then sandy flats are crossed to within a distance of 10 miles of the river, where a shaft has been sunk by the Minilya Roads Board to a depth of 62 feet, in dark shale, without striking water, whilst immediately to the eastward of this point the crystalline series again appear and continue for the remainder of the distance to the station.

From the dry well just mentioned the boundary of the granitic rocks can be traced in a south-easterly direction, sweeping past the Round Hill (which is sandstone) upon the eastern side; thence on south of A. 43 Cairn, crossing the Lyndon River just below marked tree A. 31; from there striking back to the north-east of Sugar Loaf Hill, crossing the flooded flats of the river, which it follows close upon the eastern side to A. 36, where it again crosses, following the White Quartz Hill upon the western side, from which point it strikes south-easterly on to the Minilya to a little east of Williambury Station, up to which point it has been mapped in by Mr. A. Gibb Maitland, the Government Geologist.

Traversing the river westward from A. 31, limestone conglomerates are seen resting directly upon the crystalline series in the bed of the river, to be overlaid lower down by shales. Between Windalia Pool, A. 29, and Chugareyardoo, A. 49, which is upon a branch creek to the southward, there is an outcrop of heavy schistose boulders associated with crystalline limestone; these may probably indicate shallow ground, since lines of these boulders with parallel lines of foliation are often seen outcropping, whereas if they had been a portion of the glacial series described by the Government Geologist they would have been more disturbed and ice scratched. This is the only locality in the whole area where there appears to be anything like shallow ground within the basin.

About one mile north-east of Cordalia Well, near A. 51, a fossiliferous limestone ridge rises from the plain which strikes in a north-westerly and south-easterly direction, with a well-defined dip to the south-westward. The fossils in these beds are similar to those met with upon the Irwin River, and therefore it may be assumed that these rocks belong to the Lower Carboniferous series.

To the south-westward of this ridge is a well defined range of hills, the basial beds of which are shale, whilst the capping is sandstone or quartzite; these latter beds vary from 20 to 70 feet in thickness.

This range attains its greatest elevation at the south end in Moogooloo Peak, which forms a conspicuous landmark, whilst owing to the vertical cliff-like faces presented by the heavy quartzite capping it is most difficult to climb.

This range appears to be the northern extension of the Kennedy Range, which is also similarly capped.

The beds of this range near A. 51 have a much steeper dip than at any other point noted in the district, therefore, it is either only local, or the dip of this series flattens greatly to the northward, which is quite possible, and would account for the plains without rock outcrops.

Between Cordalia Well and Winning the country is mostly low and rolling, the ranges dying away to the northward of the river, the presence of the various formations being only determined by the nature of the soil.

To the westward of Winning, after the shale hills are crossed, the surface of the country consists of a series of calcareous flat, which give place to low shale hills near the Cordalia Creek.

About ten miles west of that creek, at A. 8, there is a bold limestone range, the rocks of which dip at a low angle to the westward, whilst between it and the coast are a series of flats and sand ridges.

South from Winning along the telegraph line to the Lyndon River the country is undulating, the soil being mostly sandy and calcareous.

The beds of this district fulfil all the conditions necessary to an artesian area, consisting as they do of a series of pervious sandstones and limestones interbedded and overlaid by impervious shales of considerable thickness, the whole having a uniform dip to the westward or towards the coast. At the junction of the artesian series with the granite, the surface elevation varies from 450 to 500 feet above the sea level, the coast being about 75 miles distant; but since about 15 miles of coastal country has practically no elevation, this fall may be condensed into 60 miles, which represents from 7 to 8 feet per mile; therefore as the water level at or near the junction varies from 50 to 100 feet (according to the elevation of the surface), it will follow that a sufficient hydrostatic head cannot be obtained to cause water to rise above the surface until a distance of from 12 to 15 miles west from the outcrop of the crystalline series is reached, although in the intervening distance no doubt sub-artesian water (water rising in bore but not overflowing) will be obtained.

In support of the theory that this is an artesian area, we find in the Lyndon Valley and to the southward the unbroken continuation of the rock series, forming hill ridges, which constitute the proved area of the Gascoyne.

In conclusion, it may be stated that a very fine stretch of pastoral country was passed over, which at the present time is practically valueless, because all attempts to obtain a water supply by the means of shallow wells has so far proved futile.

HARRY P. WOODWARD,
Assistant Government Geologist.

3.—The Phosphatic Deposits near Dandaraga.

(*With a Map and 8 figures.*)

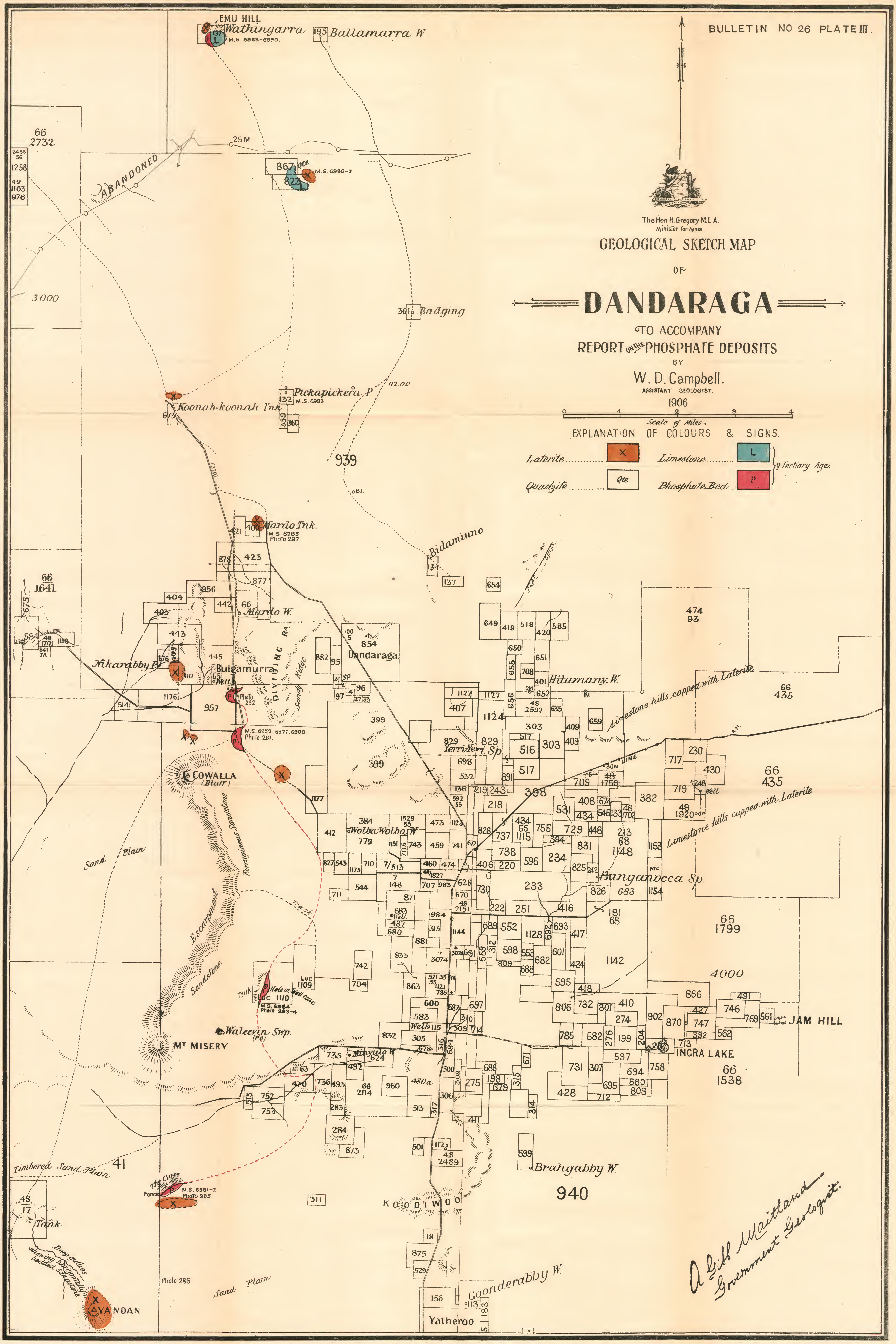
Preliminary Note.—In the month of September, 1906, a sample of a greenish ferruginous sandstone, which, on examination, was found to contain 14.96 per cent. of phosphoric acid, was received at the offices of the Geological Survey. In view of the great value to the State of the occurrence of a suitable mineral phosphate, it was considered desirable to have a geological examination of the deposit made in the field, and also to carry out certain investigations in the laboratory in connection therewith.

Mr. Campbell, Assistant Geologist, was accordingly instructed to visit the district to inquire, *inter alia*, into the extent of the deposit, its mode of occurrence, its mineralogical constituents, etc., and the utilisation of the deposit. This officer devoted a week to the investigations in the field, and made a collection of the deposits in illustration of his report. These samples were placed in the hands of Mr. Simpson for investigation in the Survey Laboratory, and a typical series are now in the Geological Survey Museum.

The report of Mr. Campbell is accompanied by a plan (Plate III.) showing the extent of the phosphatic deposit, so far as is at present known, together with a series of four photographs and four geological sections. Mr. Simpson's report contains several analyses of the different classes of the deposit.

It appears the deposit occurs in a series of beds, which have been followed across country for a distance of about 22 miles, and the phosphatic rock exposed in several places. The deposit appears to have been originally found on the Midland Railway Company's concession, though the field observations prove it to extend into Crown lands. So far as observations have as yet been carried, there appear to be three distinct classes of material amid the phosphatic deposits (*a.*) weathered rocks containing from 0.54 to 2.10 per cent. of phosphoric acid; (*b.*) ferruginous sandstones, containing phosphates mainly of iron with from 7.25 to 15.13 per cent. of phosphoric acid, the iron phosphates occurring as dufrenite and vivianite; and (*c.*) fossil bone and coprolite rock, containing from 15.32 to 39.34 per cent. of phosphoric acid.

The bone bed has been proved to be about three feet thick, whilst the underlying ferruginous sandstone, which has been more or less phosphatised by the interaction of ironstone and phosphoric acid derived from the bone beds, is at least 7ft. in thickness. The bone bed is of course the most important of the deposits, and it is possible that prospecting may result in portions of the deposit



The Hon H. Gregory M.L.A.
Minister for Mines

GEOLOGICAL SKETCH MAP

OF

DANDARAGA

TO ACCOMPANY
REPORT ON THE PHOSPHATE DEPOSITS
BY
W. D. Campbell.
ASSISTANT GEOLOGIST.
1906

Scale of Miles
0 1 2 3 4

EXPLANATION OF COLOURS & SIGNS.

Laterite	X	Limestone	L
Quartzite	Qte	Phosphate Bed	P

Limestone and Phosphate Bed: Tertiary Age.

A Gibb Maitland
Government Geologist.

H.J. Pether Government Lithographer Perth W.A.

being found to be much richer in phosphoric acid than any of the outcrops yet tested.

The matter of the geological age of the deposit is one of inference only, but I am inclined to regard it as being the northern extension of the Gingin tertiary strata.

These discoveries are of importance, and should act as a stimulant to the search for similar phosphatic deposits in that portion of the Great Coastal Plain, which extends from Perth to Geraldton, for they may easily prove to be more extensive than at present known. So far as can be judged from what is at present to be seen, there seems to be the material for a remunerative industry if properly and judiciously followed up.

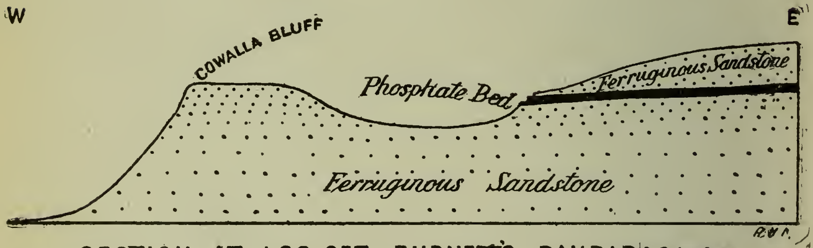
A. GIBB MAITLAND,
Government Geologist.

The locality where phosphatic deposits have been found on the Midland Railway Company's concession is on a north and south line of country passing four miles west of Dandaraga, which latter place is 22 miles to the westward of Moora, and is connected with it by a well-made road. The intervening country is largely a sandplain until about 14 miles out from Moora, when a series of low limestone hills are met with showing a considerable fertility of soil. The hills rise rather higher on the west side of Dandaraga and form the dominant range in the district. These hills are mostly well wooded, and are composed of ferruginous sandstone, they form a line of steep escarpments and bluffs towards the west, from the foot of which extend many miles of sandplains, mostly destitute of timber. These ferruginous beds are nearly horizontal, with a slight inclination to the east in places, and contain indurated bands on the top of one of which the phosphatic bed or beds occur, and are seen on a subsidiary line of escarpments about a mile back from the main line of which Cowalla Bluff forms a part, and also at the base of some white limestone or chalk-like hills thirteen miles to the north. These localities extend over a distance of about 22 miles.

The place where the phosphate samples were first obtained is about six chains south-easterly from the south-east corner of Location 957 (James Burnett's) ; here the upper portion of the outcropping ledges of rock on the track show about one foot in thickness, having a mottled green colour, which attracted the attention of Mr. James Gardiner when driving along the track, and he collected some samples and forwarded them to this Department and to the Government Analyst, when they were found to be phosphatic, containing from 10 to 15 per cent. of phosphoric acid. The source of this acid is a bone bed that overlies it and which being softer has decomposed at the surface of the ground, leaving only a few blocks scattered about. It contains fragments of bone, teeth or tusks of saurians and whitish nodules (so-called coprolites), which latter have been probably formed by the aggregation of phosphate of lime. The report of the Mineralogist and Assayer shows that the green colour of the rock is due to the mineral dufrenite, the phosphoric acid having combined with peroxide of iron to form that mineral. He also reports the presence of both vivianite (hydrated phosphate of iron) and wavellite (hydrous phosphate of alumina). The beds have thus both rock and organic phosphates.

Since my visit I have been shown specimens obtained from holes sunk adjacent to this outcrop ; these show a better grade of phosphate, and that the bone bed is at least three feet thick, and that the green alteration of the bands of sandstone extends down to ten feet depth in the deepest of the holes, which have bottomed on to very hard sandstone.

The same formation is to be seen at the ledge of rock, ¾ mile to the north near Mr. Burnett's house, but the bone bed is not so much in evidence there. (Figures 1 and 2, and Mineral Specimens **6952, 6977-80**.)

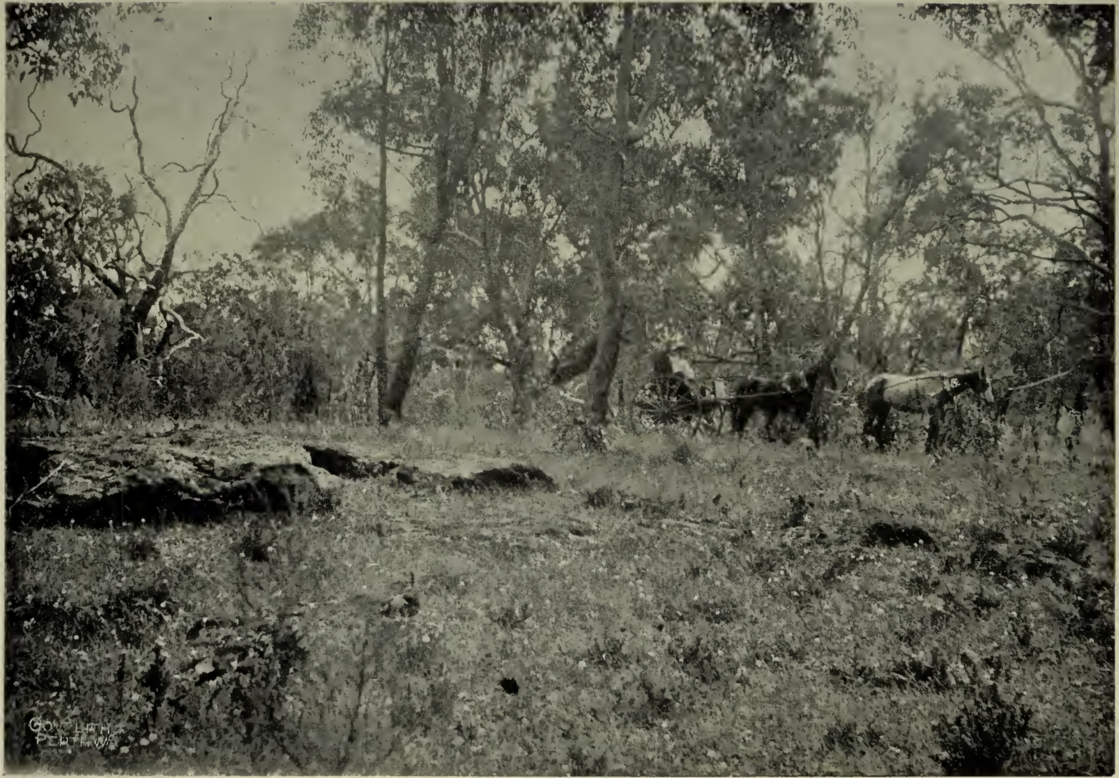


SECTION AT LOC 957 BURNETT'S DANDARAGA

Fig. 1.

Similar beds occur about 4½ miles in a direct line southerly at the western side of Location 1110 (Mr. Bower's) ; there is here a low escarpment to the west. The phosphate bed probably underlies the surface across from there to an eastern escarpment of a small gully, where there is a small cave known as the "Hole in the Wall," a distance of about 30 chains. The upper portion of this ledge is green-coloured, and is phosphatic, and a tank which has been excavated in it shows that the bone bed also exists here to a depth of six feet at least. (Figures 3, 4, and 5, and Mineral Specimen **6984**.)

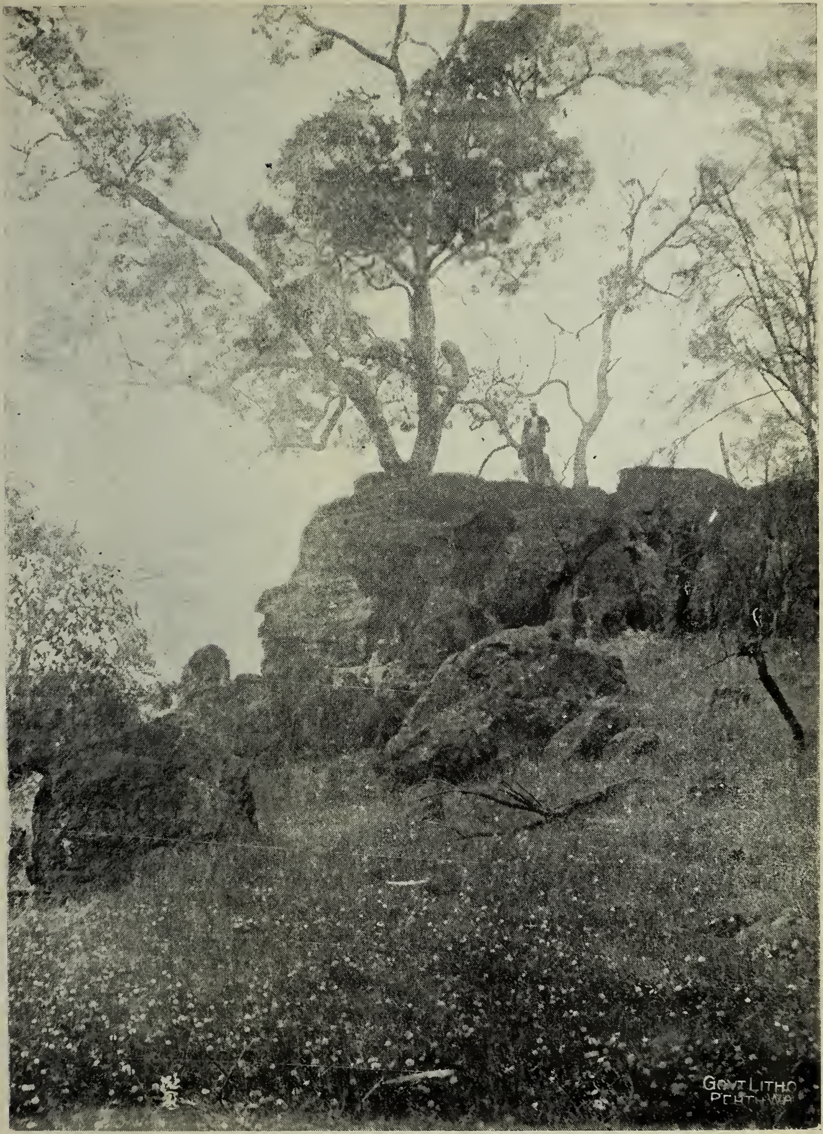
FIG. 2.



Phosphate beds, 6 chains S.E. from S.E. corner of Loc. 957, near Dandaraga, looking E.

Negative 281.

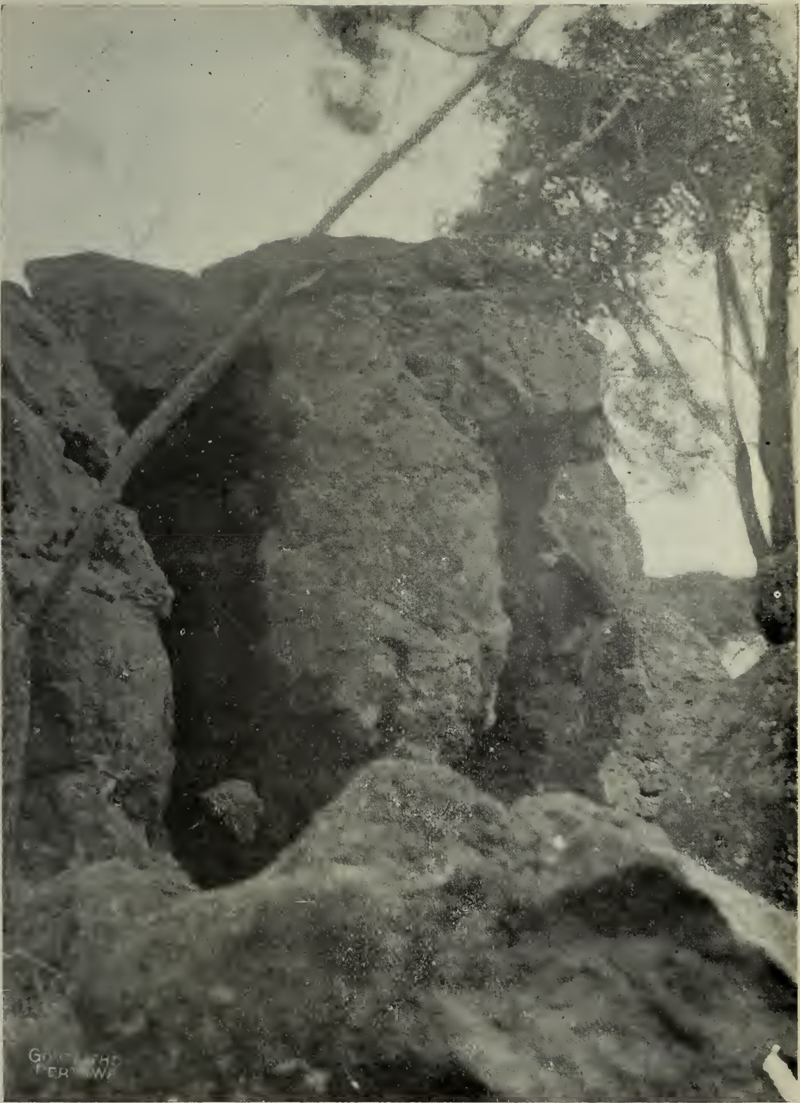
FIG. 4.



Phosphate rock forming upper surface of escarpment of Ferruginous Sandstone at Loc. 1110, near Dandaraga, looking E.

Negative 283.

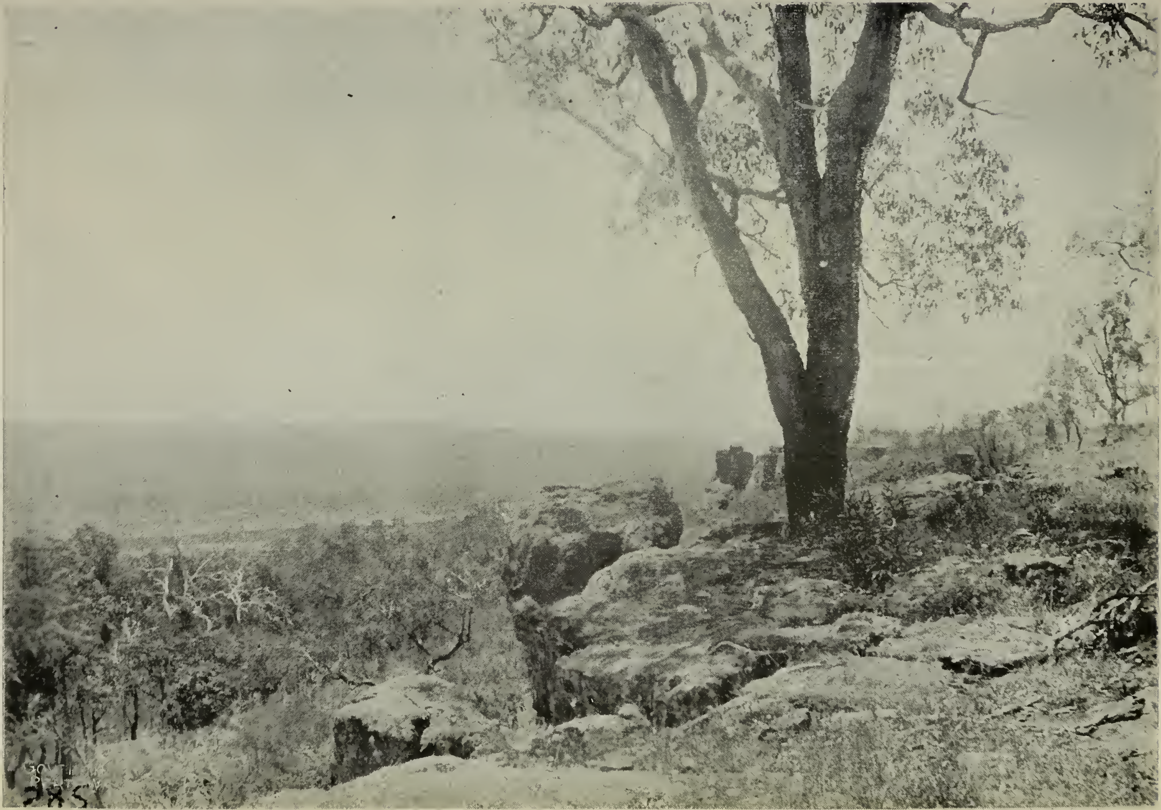
Fig. 5.



Cave, known as "Hole in the Wall," on Loc. 1110, close to Fig. 4.

Negative 284.

FIG. 6.



Phosphate bed above caves, $2\frac{1}{2}$ miles N.E. from Yandan Hill, near Yatheroo, looking E.

Negative 285.

Four miles south again from here there is a conspicuous cliff facing the north, known as "The Caves." These caves have been formed by the action of the water penetrating cracks in the hard ledge, and washing away the underlying softer rock. Heavy rain had fallen the day before my visit, and the fresh marks of running water were very plain. Some of the caves are over 50ft. long, and, in some places, 8ft. high. The upper surface of the ledge has the green-coloured rock, and above it are fragments of the bone bed and nodules. The hill top is wooded to the face of the cliff, along the foot of the cliff also there is a strip of large timber growth, but south-westerly from here the timber becomes scarcer, and at 2½ miles is the bare Yondan Hill, which I visited, but did not go beyond as the country looked unpromising, and any further outcrop of the phosphatic bed would probably have to be sought for nearer Yatheroo. (Mineral specimen **6981-2**, and Figure 6.)

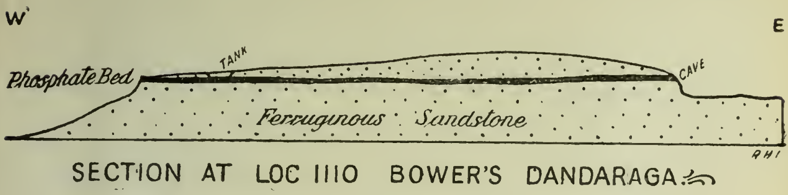


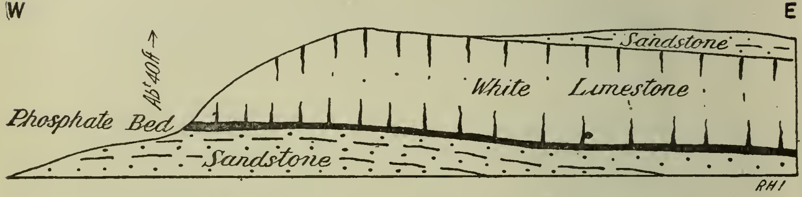
Fig. 3.

Northwards of Cowalla the escarpments disappear, and the line of hills is broken up, the timber growth lessens, and I did not hear of any ledges of this ferruginous green rock about there.

In Location 400, Mordo, a tank has been excavated in either a fine-grained ferruginous sandstone or a decomposed greenstone, the upper portion of which has a greenish colour and contains from 2.10 per cent. of phosphoric acid ; but I did not see any sign of the bone bed, as a bed of laterite of about a foot thickness conceals the underlying sandstone. The country around is flattish with only scanty timber. (See Mineral Specimen **6985**.)

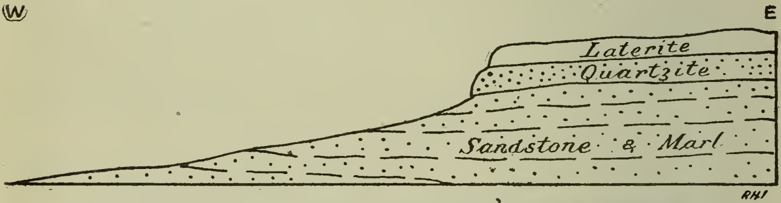
Two miles farther north is Pickera Pickera, where a similar rock outcrops near the track (Mineral Specimen **6983**) with only .54 per cent. of phosphoric acid. It is quite possible that the bone bed may never have existed here, and that the phosphoric acid at both these two locations may have been the result of the denudation of the bone bed in the neighbourhood.

Six miles farther north at Wathingarra (Emu Hill) there is a white limestone or chalky hill, the western foot of which is intercalated with sandy seams, and with them is a bone bed outcropping near the track. The greater part of the hill is composed of a very pure limestone, a sample from the top of the hill, when examined, showed a slight trace of phosphoric acid ; some silicified pieces of wood were found on the hill, probably caused by the same conditions that have solidified a white sand and gravel at Location 867 (Whitfield's), about three miles south-easterly from here, into a quartzite bed from 4ft. to 8ft. thick, which underlies about 6ft. to 10ft. of laterite. Both here and at Emu Hill there is a total absence of the ferruginous zones that are such a marked character of the other localities mentioned. (Figures 7 and 8, and Mineral Specimens **6986-90**.)



SECTION AT LOC 1137 EMU HILL DANDARAGA.

Fig. 7.



SECTION AT LOC 867 WHITFIELD'S DANDARAGA.

Fig. 8.

In each instance the bone bed evidently forms part of the sequence of the beds in the district, all being of one geological series, and it may be found that the bone bed is repeated at a higher or lower horizon on the series, and that the Emu Hill bed is not the same as that at Location 957.

In the map accompanying the report of the then Government Geologist, Mr. H. Y. L. Brown, the Gingin, Yatheroo, and Dandaraga patches of limestone are shown, and both that and the "ferruginuos claystone, limestone, sandstone, and grit" are classed as of mesozoic age (Oolitic period of the Jurassic series), and on pages 11 and 13 of his report, he says that the average thickness of these beds where best developed is 400ft., and average elevation about 600ft. above sea level, the surface accumulations of sand preventing its being ascertained whether the limestone over or underlies the ferruginous rock of the district.

The fragmentary and greatly decomposed state of the specimens that I have obtained from the outcrops of the bone beds prevents much assistance being derived from them towards the identification of their geological horizon at present. There is, however, a great resemblance of the characteristics of the bone bed series with the ferruginous sandstones of the Greenough River district which contain Jurassic fossils, and Mr. H. Y. L. Brown has mapped them as being of the same series.

In both localities the current bedding of the sandstones and the ferruginous bands of floors denote that they were formed in either estuaries or lagoons which were liable to be dried up at times causing probably the destruction of most of the marine creatures inhabiting them.

I did not hear of the occurrence of phosphatic material at any other tanks or wells along the route of travel between the above-mentioned localities, and my inquiries were necessarily more particularly directed towards the existence of the green-coloured rock, which alone appears to have been noticed by residents of the district, who, however, thought that the colour was due to the presence of copper. At Cowalla, the horizon of the phosphate bed appears to be below the summit of the bluff, but it being very steep and disadvantageous as a working ground, I did not ascertain whether it existed there. At Emu Hill there are no ferruginous ledges nor green-coloured rocks, but the bone bed probably extends along the outcrop of that horizon of the limestone hills. Around here the timber is scanty, and white gum has replaced the red gum, the neighbourhood of Cowalla being, I understand, the northernmost limit of that tree, and Yatheroo that of the jarrah. The strong growth of vegetation in portions of the district is due probably to the existence of both limestone and phosphate beds, independently or in conjunction.

It will be seen from the above particulars that there appears to be here the material for a remunerative industry, for the phosphatic deposits evidently extend over a considerable area.

The bone beds somewhat resemble the Cambridgeshire coprolite beds in England, of which I have had experience, and the procedure for the exploration and working of the deposit will be much the same, viz., by trial holes, and then excavating the open trenches, first stripping down to the bed and working up hill until the depth reached makes it too costly for the amount of phosphate obtained. The material from the bone bed would have to be concentrated by screening, washing, or hand-picking, but a difficulty presents itself through the softness of the phosphatic nodules and bones, which will require great care to prevent that material from being lost in the sandy matrix.

The Cambridgeshire coprolites and the South Carolina nodules are readily separated by either washing or screening on account of their hardness. After concentration, the phosphate lumps would then have to be ground in roller pans, when it could be sold as raw phosphate, or be manufactured into superphosphate by mixing with sulphuric acid, which produces a hydrous and water-soluble phosphate, and a sulphate of lime or gypsum.

The raw phosphate does not decompose readily, and may even take years to benefit the ground ; in the superphosphate form the phosphoric acid is more readily assimilable, and is therefore more in demand when not too costly.

The green-coloured rock which underlies, or is intercalated in the bone bed, would have to undergo a different treatment, which is referred to by Mr. Simpson in his report attached, and possibly special treatment to meet the special material would have to be devised.

For the convenience of prospectors, it may be mentioned that for the field examination of samples dissolve in warm nitric acid, then strain off the residue to a clean solution ; when cold put a few drops into a solution of ammonium molybdate, when, after a few minutes, a bright yellow precipitate should appear. If the material is insoluble in nitric acid, it may be fused in a sodium carbonate bead, and then dissolved in this acid (see p. 102 Brush and Penfold's Determinative Mineralogy). A great deal of useful general information is given on the subject of phosphates in a pamphlet by Dr. Charles Chewings, issued by the Government Printer, Adelaide, 1903.

W. D. CAMPBELL,
Assistant Geologist.

Appendix I.

LIST OF SPECIMENS IN THE GEOLOGICAL SURVEY MUSEUM FROM DANDARAGA.

Registered No.	Rock.	Obtained from.	Locality.
6977	Phosphate of Iron Rock ...	Surface	Near S.E. corner of Loc. 957, Dandaraga
6978	Do. do. ...	do.	Near S.E. corner of Loc. 957, Moora district
6979	Bone Bed	do.	do.
6980	Do.	do.	do.
6981	Laterite	do.	The Caves
6982	Laterite with Phosphate of Iron	do.	do.
6983	Laterite with Phosphate of Iron, Weathered	do.	Loc. 132, Pickera Pickera, near Dandaraga
6984	Phosphate of Iron Rock...	do.	Loc. 1110, near tank, Dandaraga
6985	Do. do. ...	do.	Mardo tank, Loc. 400, Dandaraga
6986	Quartzite capping of hill	do.	Loc. 867, Whitfield's, Dandaraga
6987	do.	do.	do.
6988	Silicified wood	do.	Loc. 1137, Wathingarra (Emu Hill), Dandaraga
6989	Bone Bed	do.	do.
6990	Limestone from top of hill	do.	do.
6992	Chalcedony	do.	1 mile east of Moora, Dandaraga
6993	Ferruginous Quartzite ...	do.	do.
7017	Bone Bed	3ft. deep	Near S.E. corner of Loc. 957, hole 5 feet deep, 3 chains east of road

Appendix II.

COMPOSITION OF THE PHOSPHATIC ROCKS.

I have examined the series of phosphatic rocks collected by Mr. Campbell at Dandaraga as far as at present possible with the limited staff at my disposal.

Roughly three main classes of material were included in the samples.

A. Weathered rocks doubtfully phosphatic.—The results obtained on these were:—

L.2613. Average of **M6983.**—Weathered ferruginous rock with a little green staining; P_2O_5, 0·54°/$_0$.

L.2616. Average of **M6985.**—Weathered greenstone (?). P_2O_5, 2·10°/$_0$

Neither of these samples are of any value whatever.

B. Ironstones carrying phosphates, mainly of iron.—The analyses of these are :—

L.	Total P_2O_5.	Ferric Oxide.	Silica and Insoluble Silicates.	Water and Organic Matter.	Carbonic Acid.
2600	7·25	32·14	47·54	7·35	Trace
2601	9·63	...	...	...	Strong trace
2614	15·13	...	...	...	Strong trace
2615	7·41	...	...	...	Trace

2600. Average of **M6977.**—Ferruginous sandstone impregnated with Dufrenite (hydrated phosphate of iron). Sample contains only 0·08 per cent. of lime. Of the phosphoric oxide present 6·63 per cent. is insoluble and 0·62 per cent. soluble when digested for a week with 1 per cent. citric acid solution. Only one-tenth therefore of the total phosphoric oxide present is available for plant food in its present state.

2601. Ink-coloured portion of **M6978.**—This is similar to the previous sample, but appears to contain as well as Dufrenite a second iron phosphate, Vivianite.

2614. Typical specimen of **M6982.**—Light brown siliceous ironstone with paler nodules.

2615. Average of **M6981.**—Heavy dark brown siliceous ironstone, with light brown concretions.

The first of these four samples is similar to the first sample brought to Perth from this locality. It showed 14·96 per cent. of phosphoric acid, and my report upon it is applicable to the present (B) set of samples.

" For a fertiliser the sample as submitted is low in phosphorus, and the amount of that constituent available for plant food in its present state appears to be very minute, dilute citric acid having an extremely slow effect upon it. Before any practical use could be made of this material means must be resorted to to render the phosphoric oxide soluble. The usual method of treating rock phosphate, viz., converting into superphosphate by treatment with sulphuric acid would be inapplicable in this case where such a large proportion of iron oxide is present. The most feasible method of utilisation seems to be the manufacture of 'Precipitated Phosphate' by solution of the phosphorus and precipitation with lime or calcium sulphide. By this means a very rich fertiliser could be obtained. If dufrenite be the only phosphatic mineral in this deposit it is evident that the highest proportion of phosphoric oxide that could be present in any part of it would be that present in pure dufrenite, viz:—28 to 32 per cent., whilst the average would be well below that owing to admixture of sand, clay, and limonite. It seems probable, however, that the original source of the phosphorus was coprolite or bone phosphate, which by interaction with iron compounds has given rise to dufrenite. Either of the former phosphates would be of more value than the last named, being both richer in phosphoric oxide and readily converted into superphosphate."

In years to come, when the steel industry is an established fact in Australia, there will probably be a demand for the more ferruginous samples for the simultaneous manufacture of basic steel and Thomas' phosphate.

C. Fossil Bone and Coprolite Rock. The prediction that the iron phosphate was a secondary mineral derived from the interaction of ironstone and phosphoric acid derived from bone or coprolite beds has been verified by Mr Campbell.

The following are analyses of typical samples of these beds:—

L.	Total P_2O_5.	Lime.	Ferric Oxide.	Silica and Insoluble Silicates.	Water and Organic Matter.	Carbonic Acid.
2602	18·26	15·80	26·42	21·27	7·83	Very small
2603	39·34	...	...	1·87	...	Small
2604	26·26	...	4·17	28·06	2·50	Small
2610	15·32	...	29·31	27·02	9·60	Very small

2602. Average of **M6979**. Yellowish and greenish mottled rock with base of ferruginous sand carrying a little dufrenite, and enclosing numerous fossil bones and lime phosphate nodules (coprolites) of all sizes. Most of the phosphoric acid in this sample is present as lime phosphate, a little, however, is present as iron phosphate (dufrenite) and a little as aluminium phosphate (wavellite). The whole of it is "acid soluble"; 7·06 per cent. of the phosphoric oxide is soluble in 1 per cent. citric acid in one week and is therefore available for plant food, 11·20 per cent. is insoluble in this solution. Such material, if very finely ground, might be used with advantage on the swamp soils of the South-West of this State, but being very slow in action compared with superphosphate would probably not be received with much favour by the farmers. Its value at the rates published by the Agricultural Department would be £2 17s. per ton. A higher grade sample of similar material has been presented to the Department by Mr. Jas. Gardiner.

2603. Bone (tusk?) from **M6979**. This is a fair sample of the large pieces of bone present in the previously described sample. It contains 85·88 per cent. of lime phosphate and only a trace of iron.

2604. Phosphatic nodule or coprolite from **M6979**. Contains 57·33 per cent. of lime phosphate, and is therefore similar to much of the lower grade coprolite and pebble-phosphate which is converted into superphosphate.

2610. Average of **M6980**. Similar to **L2602** already described, but contains no visible iron phosphate and is more porous and friable, having apparently been subjected to considerable leaching action.

Both of the samples of the bone-coprolite beds examined are too low in phosphoric oxide to be worth converting into superphosphate. That richer samples are, however, to be obtained is shown by Mr. Gardiner's specimen. With cheap locally made sulphuric acid even the lower grades might be used for the production of high-grade precipitated phosphate.

If the bones and coprolites can be successfully separated from the enclosing non-phosphatic sand rock by coarse crushing and screening, or otherwise, an excellent high-grade raw material would be obtained, carrying from 60 to 70 per cent. lime phosphate, and therefore well suited for conversion into superphosphate.

The latest published local values for phosphoric acid in fertilisers are as follow:—

	s.	d.	
Water-soluble	5	2	per unit.
Citrate-soluble	3	10	„ „
Acid-soluble	2	7	„ „
P_2O_5 in bones, offal, etc.	3	0	„ „

EDWARD S. SIMPSON,
Mineralogist and Assayer.

4.—Notes on a Meteorite from the Nuleri District of Western Australia.

(*With 6 figures.*)

The small meteorite (**5025**) here described, was presented to the writer by W. R. Feldtmann, Esq., in 1902, with the information that it was obtained from a prospector, who said he picked it up in the uninhabited interior somewhere about 200 miles east of Sir Samuel. According to this it would have been found either close to or within the boundaries of the Nuleri Land District, and it is proposed therefore to call it the Nuleri meteorite.

Its general appearance is shown by Figs. 9 and 10. It is a Siderite of the octahedrite type. Its total weight was 120.2 grammes; extreme length, 60mm.; extreme width, 46mm; extreme thickness, 22mm. It is evidently not an entire boloid but a small fractured portion of a large mass, probably fractured naturally in falling, since the fractured surfaces have a crust very similar to that on the original external surface. About one quarter of the surface exhibits the typical external appearance of a siderite being pitted and covered with a glazed surface, varying in colour from black to dark brown. The remainder of the surface is formed by broad faces of the octahedron covered by a thin coating of black magnetite. The mass is penetrated deeply in places by fractures along octahedral cleavage planes. A number of minute moist globules, brownish yellow in colour, occurred on the cleavage faces when first received. These proved on examination to be iron perchloride (Fe_2Cl_6), showing that lawrencite (iron protochloride) is a constituent of the mass.

Taking advantage of the deep fractures, portions weighing in all 10.7 grammes, were broken off with a cold chisel for chemical and structural examination, leaving the main mass weighing 109.5 grammes.

Internal structure.—A cleavage flake, 30 millimetres long and 3mm. thick, was carefully polished on one side and then etched with nitric acid of normal strength for about two minutes in order to develop the internal structure. This was found to be very interesting, a beautiful damascened structure being brought out. This is well shown in Fig. 11. A similar structure is recorded by Fletcher as occurring in the Youndegin iron, though nothing resembling it appears on the fragment of that iron in the Perth Museum.

The different constituents observed were three, viz.:—

(1.) A dull grey iron-nickel alloy forming the greater part of the surface. This was evidently the constituent most attacked by the acid.

(2.) A much brighter iron-nickel alloy, but little affected by the acid and occurring in numerous long slightly curved lenticular

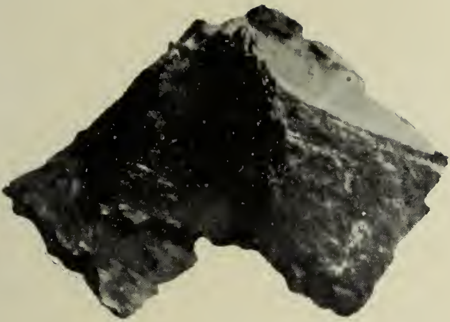


Fig. 9. Obverse.

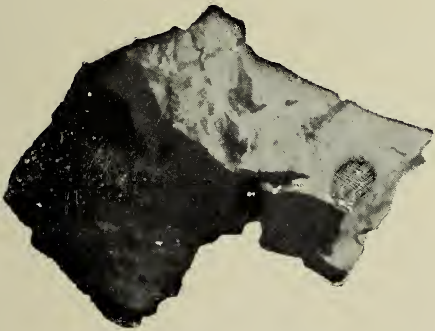


Fig. 10. Reverse.

Nuleri Meteorite. (Natural size.)

Photo.: E. S. Simpson.

wisps, for the most part from one-twentieth to one-fifth of a millimetre in thickness, as seen in Figs. 11 and 12. There are two interlacing sets of these lenticles each roughly parallel to one of the octahedral cleavages, one being much more developed than the other. No lenticles appear to follow the third cleavage. The second, less prominent set, is best seen in Fig. 13, but may also be seen in Fig. 11. On one portion of the surface this mineral is much more largely developed, forming an M shaped area, one leg of which is seen to cross the centre of Fig. 12.

(3.) A brilliant tinwhite mineral occurring in very small amount, and that very irregularly distributed, being confined to two widely separated areas. Its outline at one of these points resembles Arabic writing, as seen in Fig. 14 ; at the other shown in Fig. 13 there is a singular tabular crystal parallel to a cleavage, about 2mm. long and 0.3mm. wide. In both cases the illumination of the surface when the photographs were taken was such as to suppress the brilliancy of this mineral. It appears therefore to be almost black. This mineral is probably schreibersite (phosphide of iron and nickel).

The only other notable point brought out by etching was the octahedral cleavage in three directions at an angle of 60 degrees with one another, the fourth cleavage being parallel to the surface of the plate.

Chemical composition.—A fragment of the meteorite weighing about 5 grammes was carefully cleaned by filing, etc., and finally analysed, with the results given below. For comparison I have attached the analyses of three of the only other five undoubted meteorites yet discovered in this State. No analyses would appear to have been made of the Mooranoppin and Mt. Stirling irons :—

Name	Hamersley Range (Roebourne).	Ballinoo (Mt. Erin).	Youndegin.	Nuleri.
Class.	Om	Off	Og	?
Iron	90·91	89·91	92·67	93·57
Nickel	8·33	8·85	6·46	5·79
Cobalt	·59	·74	·55	·41
Magnesium	*Nil*	*Nil*	·42	·09
Copper	*Nil*	Trace	Trace	Trace
Carbon	Trace	Trace	·04	·01
Phosphorus	1·16	·50	·24	·13
Sulphur	Trace	Trace	*Nil*	Trace
Silicon	·01	Trace	*Nil*	*Nil*
Chlorine	...	...	...	Trace
Total	100 00	100·00	100·38	100 00
Sp. Gr.	7·78	7·8	7·86–7·72	7·79

Assuming that the whole of the phosphorus is present as schreibersite, the mineral composition of the meteorite would be—

Schreibersite	0.84 per cent.
Nickel-iron alloys	99.16 per cent.
Lawrencite	Trace.

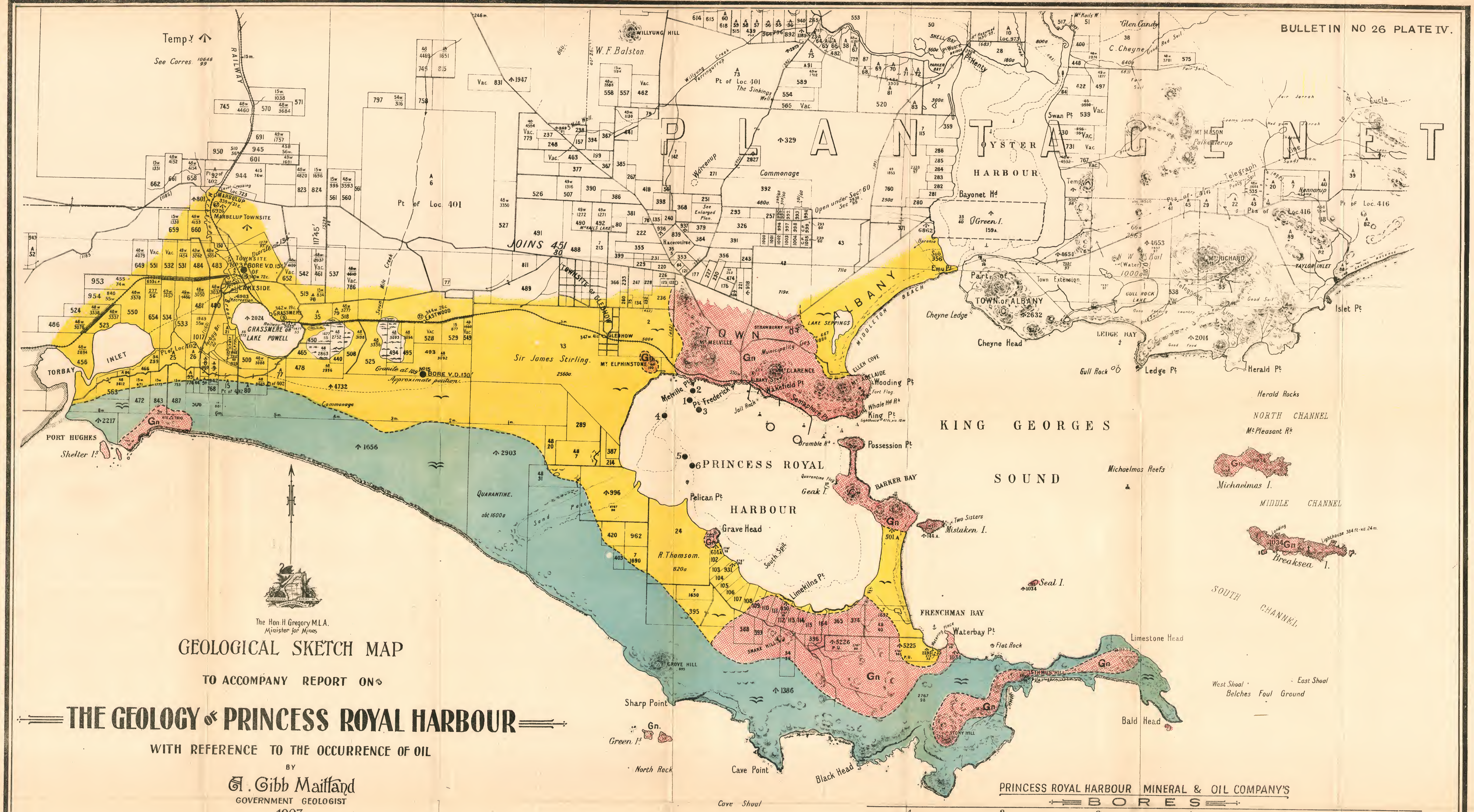
Owing, however, to the very irregular distribution of the constituents disclosed by polishing and etching, and to the fact that only a small fragment (15 grams.) could be used in making the analysis, the chemical composition given above must be looked upon as only approximate for the whole mass.

EDWARD S. SIMPSON,
Mineralogist and Assayer.

1	6	
4	ter	1' to 1'
3	nd & Shells	10'6" . 11'6"
od & 9	ocolate sand	23'6" . 35'
	wn sand	9' „ 44'
lstone loured aces of oil, 9	ocolate clay dules	8' „ 52'
l 3'	ey sand dules	38' „ 90'
rous 6' traces of oil	wn Sand nodules	4' „ 94'
tz e Granite 3	dstone nodules	2' „ 96'
t oil 12	nd white Kaolin	
9	h sulphides	
t 3	dules.	9' „ 105'
l came up.		

Government Lithographer. Perth. W.A

BULLETIN NO 26 PLATE IV.



The Hon. H. Gregory M.L.A.
Minister for Mines

GEOLOGICAL SKETCH MAP

TO ACCOMPANY REPORT ON

THE GEOLOGY OF PRINCESS ROYAL HARBOUR

WITH REFERENCE TO THE OCCURRENCE OF OIL

BY

A. Gibb Maitland
GOVERNMENT GEOLOGIST
1907

0 1 2 3 4
Scale of Miles.

EXPLANATION OF COLOURS AND SIGNS

Recent Superficial Deposits	🟨
Aeolian Deposits	🟦 ≋
Granite	Gn

PRINCESS ROYAL HARBOUR MINERAL & OIL COMPANY'S

BORES

1		2		3		4		5		6	
Water	4' to 4'	*Water*	4' to 4'	*Water*	6' to 6'	*Water*	4' to 4'	*Water*	1' to 1'	*Water*	1' to 1'
Shells	3' . 7'	*Shells & Sand*	5' . 9'	*Sand & Shells*	6 . 12'	*Sand & Shells*	10' . 14'	*Sand & Shells*	17' . 18'	*Sand & Shells*	10'6" . 11'6"
Sand with wood & Charcoal	9' . 16'	*Brown clay & sand*	3' . 12'	*Brown sand no clay*	6 . 24'	*Brown Sand streaks clay*	12' . 26'	*Brown sand*	4' . 22'	*Chocolate sand*	23'6" . 35'
Clay		*Blue tint clay & sand*	10' . 22'	*Brown slippery materl.*	3' 27'	*Dark sand with traces of oil. black specs.*	6' . 32'	*Sand with deposit black specs.*	10' . 32'	*Brown sand*	9' . 44'
Porous Sandstone with brown coloured precipitate & traces of oil	9'11" . 26'	*Sand black deposit*	9' . 31'	*Brown Sand black deposit*	3' . 30'	*Grey Sand hard black pieces*	8' . 40'	*Grey Sand.*	56' . 88'	*Chocolate clay nodules*	8' . 52'
Clay with oil	3' . 26'3"	*Black clay & Sandstone*	8' . 39'	*Brown Sand slippery in places*	6' . 36'	*Grey sand & shells*	6' . 46'	*Coarse Brown sand*	12' . 100'	*Grey sand nodules*	38' . 90'
Dark brown porous sandstone with traces of oil	6'6" 32'4"	*Dark Sand*	1 . 40'	*Dark chocolate material. black spots*	6' . 42'	*Black clay*	7' . 53'	*White clay like pipe clay nodules*	5' . 105'	*Brown Sand nodules*	4' . 94'
dark spots Quartz & Granite	3' . 33'	*Whitish sand*	8' . 48'	*White grey sand spots black sediment*	3' . 45'	*Grey clay & shells*	3' . 56'	*Coarse brown water sand*	4' . 109'	*Sandstone nodules*	2' . 96'
Sand without oil	12 . 45'	*Granite with a little hornblende*	3' . 48'3"	*Grey Sand with black spots & white clay*	9' . 54'	*Brown sand & fresh water*	8' . 64'			*Sand white kaolin with sulphides nodules.*	9' . 105'
Clay & Sand	9' . 45'9"			*Brown clay with sandstone nodules*	8' . 62'	*Black clay & nodules*					
Granite cut shot fired & oil came up.	3' . 46'			*Green clay & sand*	8' . 70'						

H. J. Pether. Government Lithographer. Perth. W A

5.—The Geology of Princess Royal Harbour with reference to the occurrence of oil.

(*With a Map.*)

The idea of the possibility of the occurrence of oil-bearing rocks in Princess Royal Harbour appears to have been very largely based upon the fact that during the progress of dredging operations therein oil rose to the surface, and pieces of bitumen were brought up by the Government dredge.

This led to the formation of the Princess Royal Harbour Mineral and Oil Company for the purpose of prospecting for both mineral and oil ; and an application to the Department for State aid in the prosecution of the venture.

A personal inspection of about twelve days' duration was made by myself of the harbour and its surroundings, for the purpose of acquiring the necessary data at first hand.

A good deal of geological information on the vicinity of Albany appears in the various official and other reports which have appeared as far back as the year 1879 ; and as these contain some information which has an important bearing upon the question, they are somewhat freely quoted.

The geological structure of Bald Head at the entrance to King George's Sound was described by Vancouver in 1791 :—

> The principal part of this country appeared to be Coral, and it would seem that its elevation above the ocean is of modern date, coral being found on the highest hills we ascended, particularly on the summit of Bald Head. In these fields of coral, seashells were in great abundance. (*a*)

Darwin, however, seems to have been the first to have correctly grasped the geological structure of King George's Sound :—

> This settlement is situated at the south-western angle of the Australian continent. The whole country is granitic, with the constituent minerals sometimes obscurely arranged in straight or curved laminæ. . . . . These plutonic rocks are, in many places, intersected by trappean dykes. In one place I found ten parallel dykes ranging in an east and west line; and not far off, another set of eight dykes, composed of a different variety of trap, at right angles to the former ones. . . . The lower parts of the country are everywhere covered by a bed, following the inequalities of the surface of a honeycombed sandstone, abounding in oxides of iron.
>
> A calcareous deposit on the summit of Bald Head, containing branched bodies, supposed by some authors to have been corals, has been celebrated by the descriptions of many distinguished voyagers. It folds round and conceals irregular hummocks of granite at the height of 600 feet above the level of the sea. It varies much in thick-

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(*a*) Voyage of Discovery, Vol. I., pp. 165-6, 1801.

ness; where stratified, the beds are often inclined at high angles, even as much as at 30 degrees, and they dip in all directions. These beds are sometimes crossed by oblique and even-sided laminæ. The deposit consists either of a fine white calcareous powder, in which not a trace of structure can be discovered, or of exceedingly minute rounded grains of brown, yellowish, and purplish colours, both varieties being generally, but not always, mixed with small particles of quartz, and being cemented into a more or less perfect stone. . . . Both of the above mentioned varieties of calcareous sandstone frequently alternate with, and blend into, thin layers of a hard substalagmitic rock, which, even when the stone on each side contains particles of quartz, is entirely free from them; hence we must suppose that these layers, as well as certain vein-like masses, have been formed by rain dissolving the calcareous matter and reprecipitating it. . . . Each layer probably marks a fresh surface, when the now firmly cemented particles existed as loose sand. These layers are sometimes brecciated and recemented, as if they had been broken by the slipping of the sand when salt. I did not find a single fragment of a seashell; but bleached shells of the *Helix melo*, an existing land species, abound in all the strata; and I likewise found another *Helix* and the case of an *Oniscus*.

The branches are absolutely undistinguishable in shape from the broken and upright stumps of a thicket; their roots are often uncovered and are seen to diverge on all sides; here and there a branch lies prostrate. The branches generally consist of the sandstone, rather firmer than the surrounding matter, with the central parts filled, either with friable calcareous matter, or with a substalagmitic variety; this central part is also frequently penetrated by linear crevices, sometimes though rarely containing a trace of woody matter. These calcareous branching bodies appear to have been formed by fine calcareous matter being washed into the casts, or cavities, left by the decay of branches and roots of thickets, buried under drifted sand. The whole surface of the hill is now undergoing disintegration, and hence the casts which are compact and hard are left projecting. In calcareous sand at the Cape of Good Hope I found the casts, described by Abel, quite similar to these at Bald Head; but their centres are often filled with black carbonaceous matter, not yet removed. It is not surprising that the woody matter should have been almost entirely removed from the casts on Bald Head, for it is certain that many centuries must have elapsed since the thickets were buried; at present, owing to the form and height of the narrow promontory, no sand is drifted up, and the whole surface, as I have remarked, is wearing away. We must therefore look back to a period when the land stood lower, of which the French naturalists found evidence in upraised shells of recent species, for the drifting on Bald Head of the calcareous and quartzose sand, and the consequent embediment of the vegetable remains. . . . Reflecting on the stratification of the deposit on Bald Head; on the irregularity of alternating layers of substalagmitic rock; on the uniformly-sized and rounded particles, apparently of seashells and corals; on the abundance of land shells throughout the mass, and, finally, on the absolute resemblance of the calcareous casts to the stumps, roots, and branches of that kind of vegetation, which would grow on sand hillocks, I think there can be no reasonable doubt, notwithstanding the different opinion of some authors, that a true view of their origin has been here given (*a*).

These observations of Darwin's, which have been quoted at length, are of importance in that they conclusively prove that the

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(*a*) Geological Observations. Chas. Darwin, 2nd Edition, 1876, pp. 160-166.

corals of previous writers are calcified branches of trees, and the marine shells are identifiable with the recent land shells, observations which have a bearing upon the occurrence of oil in the formation.

Mr. H. Y. L. Brown, writing in August, 1872, in reference to what is evidently the same formation, stated :—

> Along the coast, in a more or less broken line, on the southern and western coasts, never extending inland more than a few miles, there are hills and ridges composed of beds of calcareous grit, sandstone, and limestone, rising from below sea-level to a few hundred feet above it.
>
> On the southern coast these occur only as patches, but on the western as an almost continuous strip, extending from Cape Leeuwin to the Murchison River and probably beyond. The presence of this formation appears to be due to the growth of coral reefs, upon which shells, sand, etc., have accumulated and become consolidated by the infiltration of water containing lime in solution. As a rule, the different layers of calcareous sandstone, limestone, etc., are horizontal, though often false bedded. They contain fossils, some of which are but little different from those now existing on the shores of the ocean surrounding this portion of the continent. (*a*)

And in 1892 Mr. H. P. Woodward reported :—

> On the south side of Princess Royal Harbour, and from it to Torbay, a line of limestone hills forms the coastal range for a distance of about nine miles, whilst to the northward sandy and swampy flats with low ferruginous sandstone hills extend nearly as far north as Mount Barker, a distance of about 25 miles, spreading out to 15 or 16 miles in width between the Hay and Kalgan Rivers. In this large basin a bore has been put down 68 feet by Mr. Parry at Eastwood, 7½ miles on the railway from Albany, the property of Mr. Powell, when the following section was obtained:—

Sandy peat	8ft. 6in.
Ferruginous sandstone	1ft. 0in.
Sand and black clay	5ft. 6in.
Quicksand	5ft. 0in.
Ferruginous sandstone	ft. in.
Quicksand	30ft. 0in.
Stiff black clay	4ft. 0in.
Quicksand	10ft. 0in.
Brown coal, quicksand	3ft. 0in.
Total	67ft. 1in.

> At this depth the bore most unfortunately fell in, so it still remains undetermined as to whether true coal measures do exist beneath this formation or not. The sample is of a dull sooty black colour, showing a good deal of vegetable structure. It is not highly mineralised but fairly compact, soft, friable, and soils the hand. The fracture is irregular, showing a laminated structure. It does not ignite readily, but when made red-hot it burns slowly, giving out a good deal of heat, and when ignited in a tube it gives off a small quantity of gas, tar, and water.

(*a*) On a Geological Exploration of that portion of the Colony of Western Australia lying Southward of the Murchison River and Westward of Esperance Bay. Perth : By Authority, 1873, p. 14.

> An analysis yielded the following result:—
>
> | | |
> |---|---|
> | Water | 6.275 |
> | Volatile matter | 18.84 |
> | Fixed carbon | 14.835 |
> | Ash | 60.05 |
>
> The percentage of water is low for a coal of this class, the volatile matter, consisting of luminous and non-luminous gases, is also low; so is the fixed carbon, whilst the quantity of ash is enormous. The coke was in the form of a fine sooty powder, whilst the ash was light, and of a creamy colour. It is of no commercial value. . . .

In the same report Mr. Woodward states :—

> The hills along the South Coast are of two ages, those forming the main coastal range being the older. They consist of a series of limestones and shaley sandstones dipping at an angle of 40 to 45 degrees to the north-east, or under the flat in which the boring operations have been carried on. In these outcrops no organic remains were visible, but to judge from their dip, which is persistent for a distance of nine miles, they must be of considerable antiquity, as we know that very little disturbance has occurred in the Mesozoic Period.
>
> At the south-east end of this range, and to the south of Princess Royal Harbour, the limestones are white, earthy, and contain fragments of hard cream-coloured limestone; but the sandy shales are entirely absent. Although these hills run in the same direction as those farther to the westward, they have no well defined bedding, and are probably the passage or junction beds between the Mesozoic sandstone, which outcrops all down the coast to the eastward, and the older rocks met with here. These Mesozoic sandstones make their last appearance on the side of Mount Clarence, which is on the north side of the harbour, where a sample obtained in sinking a well contained the characteristic fossils, but no fossils have yet been found in these rubbly limestones. . . . It is evident that a large basin, surrounded by granite, does exist, and that rocks, probably of Palæozoic age, outcrop on its southern side (*a*). . . .

In the year 1900, a report upon boring for coal near Albany was prepared by myself, and full details given regarding the 16 bores which had been sunk in the vicinity. The deepest bore was carried down to a depth of 234ft., and in every case the floor of the older crystalline rocks upon which the beds were laid down was unequivocally reached. (*b*)

Princess Royal Harbour is about 4½ miles long in a direction of about north-west and south-east, with a width of about 2½ miles. The harbour itself is very shallow, and particularly so at its north-western end.

Lying to the south of the railway line, and between it and the coast, is a strip of low-lying land connecting the head of the harbour with Grassmere and Torbay Inlet.

There are very strong grounds for believing that Princess Royal Harbour and Torbay Inlet were at one time connected, and that the high ground extending from Limestone Head to Port Hughes formed

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(*a*) General Report by the Government Geologist for the year 1892. Perth: By Authority, 1893, pp. 3 and 4.

(*b*) Annual Progress Report of the Geological Survey for the year 1900. Perth: By Authority, 1901, pp. 16-20.

an elongated ridge separated from the country to the north by a more or less extent of sea water.

Several bores have been put down in this low ground, and in every case was the floor of the older crystalline rocks met with, the greatest depth being 234ft. Full details regarding these bores can be found in the Annual Progress Report of the Geological Survey for the year 1900, pp. 16-20.

The high ground on the north side of the Princess Royal Harbour, including Mounts Adelaide, Clarence, Melville, and Elphinstone, is composed of granite of the type which occupies such a large area to the north. This granite is traversed by greenstone dykes, some of which can be seen on the beach near the gasworks.

The high ground upon which the Quarantine Station is built is also made up of granite ; this granite also is traversed by numerous dykes of greenstone, many of which may be seen on the coast between Barker Bay and Mistaken Island. These dykes are pretty well all parallel, practically vertical, and have an average strike of about 101 degrees. Some of the dykes contain masses of granite, which have been caught up during the injection of the basic magma. The granite mass of the Quarantine Station extends south-east, and forms Mistaken and Seal Islands, and the rock underlying the more recent beds of Limestone Head.

On the south side of the harbour at Grave Head (Stuart's Head of Admiralty Charts) is a fairly extensive belt of granite which reaches down to sea level. This patch is separated by a comparatively thin cover of recent deposits from a much larger and more extensive area, which extends from Limekilns Point (Limeburner Point of the Admiralty Charts) to the summit of Snake Hill, 320ft. above sea level. At Limekiln Point the granite is overlaid by a thin belt of sandy limestone, which occupies a narrow strip round this portion of the beach. The limestone, which forms the summit and flanks of Snake Hill, extends southwards and forms the northern slopes of that high ridge which separates Princess Royal Harbour from the Southern Ocean. Granite was also met with in two of the bores (Nos. 1 and 2) put down in Princess Royal Harbour by the Mineral and Oil Company, at depths of 46ft. and 48ft. respectively. These two bores were put down near the north shore, not far from Melville Point (Testing Point of the Admiralty Charts). The old granitic floor was pierced at a depth of 109ft. in a bore a mile south of the Eastwood Railway Station, whilst at Torbay Junction, bottom was reached at 134ft., after passing through variable thicknesses of drift sand and clay.

The granite also makes its appearance again in great force in the high ground upon which the Trig. Station (470ft.) near Port Hughes has been erected. Stony Island, on the south coast, due west of Grove Hill and due south of Eastwood is also of granite.

These observations indicate perfectly clearly that the landlocked Princess Royal Harbour is merely a relatively shallow depression, resting upon a floor of ancient crystalline rocks. This fact is of importance in its bearing upon the possibility of mineral oil in the harbour.

From Port Hughes, at Torbay Inlet, to Limestone Head is a line of very high perpendicular limestone cliffs, which were carefully examined in two localities ; these beds form most conspicuous features in the landscape, and in places are exceedingly picturesque, owing to the number of caves and caverns into which they have weathered. These beds rise to a height of nearly 700ft. above sea level. These limestones are aeolian deposits, consisting practically of shell sand, cemented in places into solid rock owing to the action of rain water.

The shell sand is converted into a limestone of sufficient hardness to ring like a bell when struck with a hammer ; there are, in addition, several softer chalklike beds, which pass by almost insensible gradations into a very hard compact stone.

Landwards these aeolian deposits terminate in a more or less regular smooth bank or face, to which layer after layer is gradually added. The irregular current bedding of these deposits gives the appearance of limestones dipping at varying angles from the horizon, and apparently overlaid by nearly horizontal beds.

These aeolian deposits attain their greatest development on the sea coast to the south of Princess Royal Harbour. Isolated fragments and blocks of the chalklike limestone are occasionally dredged up in the harbour, along with piece of drift asphaltum, etc., of extreme origin.

A very recent formation occurs at many points round the harbour, and consists of a somewhat peaty ferruginous, partly consolidated, sand " associated with the formation carrying bitumen and traces of oil." At several places there exudes from this formation a compound of iron, which, when floating on the surface of the water, shows a play of prismatic colours, very often mistaken for those produced by some oils.

A scum of this kind can very easily be distinguished from that produced by oil in that the scum from an iron compound of this kind will readily break up into irregular fragments on being stirred but if of oil it will form bands of colour.

At times there may be seen floating about Princess Royal Harbour patches of an oily substance, which have been claimed to have been seen rising from beneath the water at several portions of the harbour, and to be an indication of an oil-bearing formation beneath.

A sample of this shown to me was associated with fine coal dust, and had the characteristic odour of machine oil, such as is in use in many of the steamers frequenting the harbour.

There is nothing in the geological constitution and structure of Princess Royal Harbour to in any way indicate that the occurrence of mineral oil is probable ; whilst the wrong hypothesis as to the source of the bitumen dredged up and the oil floating about on the surface of the water, appears to have led to money being needlessly spent in boring, etc.

A. GIBB MAITLAND,
Government Geologist.

6.—Notes upon the Geological Map of the Greenough River District.

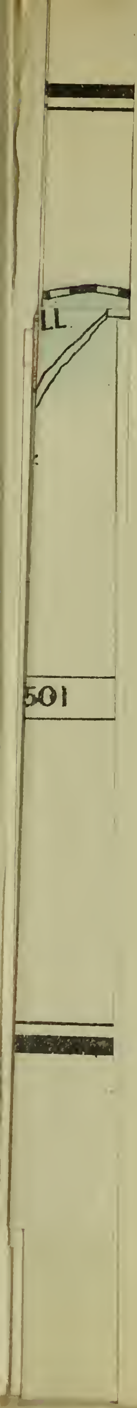
(*With a Map, Plate VI. and a Geological Section Plate V.*)

The area examined extends from near the Wizard Peak to Eradu, and includes the Minnenooka, Sandspring, and Tibraddon areas. The distance across in a direct line is about 18 miles, but by the course of the river it is about 45 miles.

Granite and garnetiferous gneiss forms the river bed from below Glengarry to the road crossing at Loc. 409, and extends from the base of Wizard Peak and of the adjacent flat-topped hills to Minnenooka and nearly to the Sandspring homestead, and northward to Tibraddon, and eastward from there to Wicherina Spring, about 3½ miles from Eradu ; only three small diorite dykes were seen and very few quartz reefs. These crystalline rocks attain an elevation of nearly 1,000 feet in places. In other portions of the district they are overlaid by a series of sandstones and conglomerates, which are mostly horizontal, but have in places an inclination of about 4 degrees to the south. The upper 200 feet of these beds on the western escarpments of the granite have occasional argillaceous and marly bands, which are mostly fossiliferous, containing marine shells of apparently jurassic age ; 250 samples of these fossils were collected, together with fragments of wood which occur in beds below or interstratified with the beds of marine shells.

The whole sedimentary beds vary greatly in character; they frequently exhibit current bedding, and are evidently shallow water deposits; some of the white sand rock or sandstones are saline; where this is the case there are argillaceous sandstones below them. The sandstones are frequently so ferruginous as to have the appearance of an ironstone, and laterite frequently occurs on their surface. This laterite is often difficult to be distinguished from the ferruginous beds themselves. The sandstones also form the sand plains occupying all the highest ground towards the north and east of the area described and beyond.

There appears to be a probability that there are two formations of different ages comprised in these sandstones, the older may be of permo-carboniferous, and the younger of jurassic age. The former was laid over the then submerged hills and valleys of the granite and gneiss rock, and may have become eroded towards the western slopes of the granite, and afterwards both were overlaid by jurassic sandstone.



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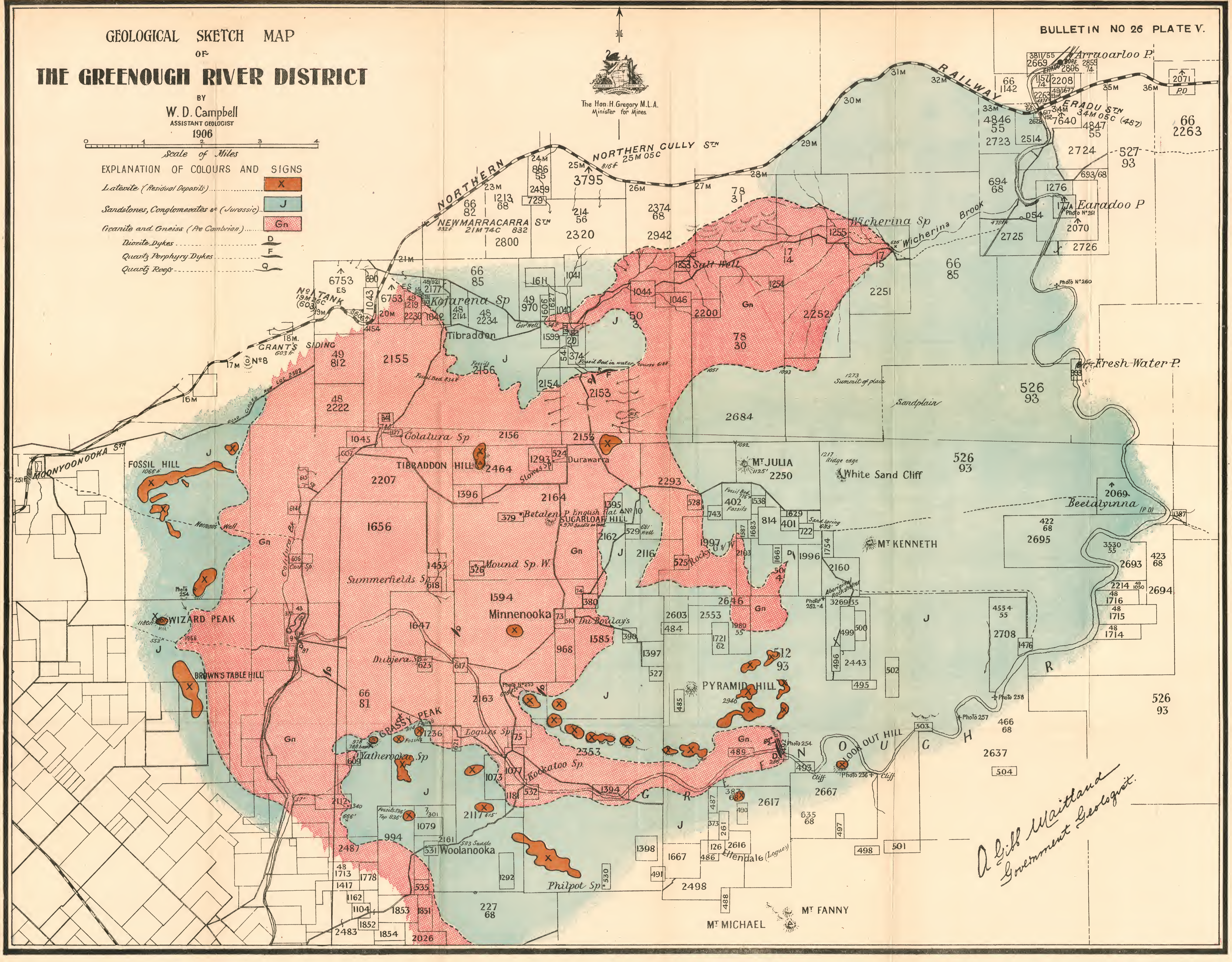
BULLETIN NO 26 PLATE V.

GEOLOGICAL SKETCH MAP OF
THE GREENOUGH RIVER DISTRICT

BY
W. D. Campbell
ASSISTANT GEOLOGIST
1906



A Gibb Maitland
Government Geologist.

H.J Pether, Government Lithographer, Perth W A

The majority of the fossiliferous horizons occur in the uppermost beds and are often covered directly by laterite; but fossils appear to occur also over 100 feet below these, as in the valley above the Tibraddon homestead.

The accompanying general section (Plate VI.), which I have drawn, shows the extent of the information at present obtainable, while the map (Plate V.) shows the area coloured geologically in as much detail as the month at my disposal permitted.

No shale or coal beds were seen, but these may possibly exist at a lower depth than has yet been reached in the Greenough area by boring.

The brackish and saline character of the pools of that portion of the Greenough River below Beetalyianna Point appears to be due to the saline sandstone which occur below that point. A sample of water from one of the pools that was in process of being dried up. was obtained for the Analyst's examination. Springs are fairly plentiful in the granite area and afford good potable water. Good supplies of water have also been obtained by wells sunk 30 to 40 feet into the sandstone at Sandspring; at the latter place an excellent spring also occurs in the sandstone at that homestead, but elsewhere the well water is mostly brackish.

W. D. CAMPBELL,
Assistant Geologist.

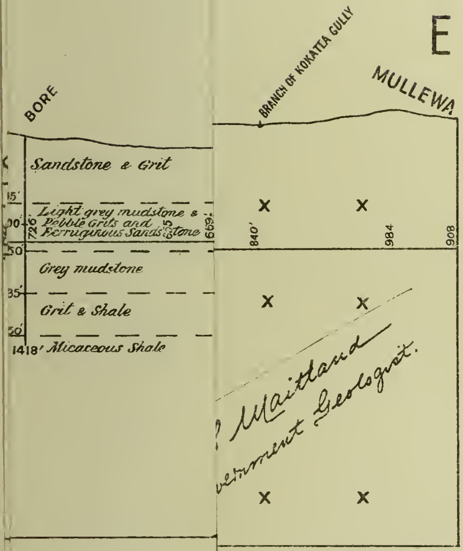
NOTE.—For a list of the Champion Bay Jurassic Fossils, *see* page 60.

Appendix I.

LIST OF SPECIMENS IN THE GEOLOGICAL SURVEY MUSEUM FROM THE GREENOUGH RIVER.

Reg. No.		
6661.	Diorite, 1 mile south of Tibraddon Homestead, crossing gully, Microscopic Section made	3 specimens
6662.	Diorite, Loc. 492, in river bed below road crossing	several small specimens
6663.	Aphanitic Diorite, ½-mile north of Quarry Hill and 1 mile south of Sandspring Homestead	1 specimen
6664.	Granite, adjoining diorite dyke specimen 6661	1 specimen
6665.	Granite, 1 mile south of Tibraddon Homestead, in gully	1 specimen
6666.	Granite, Wicherina Spring	2 specimens
6667.	Graphic Granite, centre of Loc. 1236, Snake Farm	3 specimens
6668.	Micaceous Sandstone, near Loc. 492	1 specimen
6669.	White Saline Sandstone, upper part of cleft near Photo. 259	3 specimens
6670.	Sandstone, 2 chains north-east of Photo. 259	3 specimens
6671.	Argillaceous bed in river cliff below specimen 6669	1 specimen
6672.	Ferruginous Sandstone, near Loc. 1236	1 specimen
6673.	Stratified kaolinized granitic material	1 specimen
6674.	White Sandstone, near Loc. 1236, Snake Farm	1 specimen
6675.	Fibrously crystalline siliceous bed, top of hill, west of Loc. 492	1 specimen

O 26 PLATE VI.

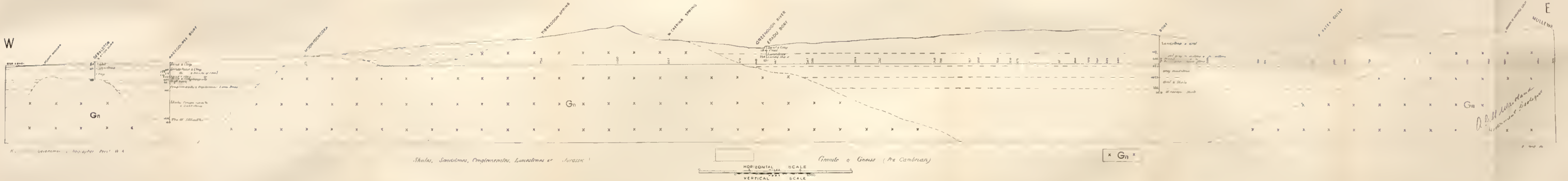


R. H. Irwin del:

The Hon H Gregory M L A
Minister for Mines

GENERALISED GEOLOGICAL SECTION FROM GERALDTON TO MULLEWA

BY
W D Campbell
ASSISTANT GEOLOGIST
1906



7.—Recent Advances in the Knowledge of the Geology of Western Australia.

(Being the PRESIDENTIAL ADDRESS by A. GIBB MAITLAND, F.G.S., Government Geologist of Western Australia, and formerly of the Geological Survey of Queensland, delivered in Adelaide before Section C of the Australasian Association for the Advancement of Science, on the 8th of January, 1907.)

My first duty in assuming the position of the Presidentship of the section of Geology is to express to you my deep sense of gratitude for your confidence in my devotion to the welfare of our science implied in the election of one who, owing to the exigencies of official life, has had few opportunities during the last 19 years of becoming personally acquainted with the majority of the "Brethren of the Hammer" in Australia. The honour, however, is enhanced by the fact that in addressing the members of this section of the Association in Adelaide, I am speaking in the capital of a State which has contributed—in the persons of Messrs. H. Y. L. Brown and H. P. Woodward—so much to the progress of official geological research in Western Australia.

The civilising value of scientific investigation, such as is evidenced by a gathering of this kind, where the "hammerers" from the West meet those from East, upon common ground, for the purpose of discussing, consolidating, and recording the work of the past, must tend to link all parts of this continent together, and time perhaps will show that it may fall to the lot of the Australian men of science to materially assist in the solution of the problem of preserving those harmonious relationships and the strengthening of those ties which are so severely taxing the combined resources of political diplomacy.

It is, I believe, customary for the occupant of the Presidential chair to offer a few observations on some special department of the science which seems in his opinion worthy of attention, and I am therefore unwilling to depart from what must be regarded as traditional usage. On looking over the list of subjects reviewed by my predecessors in this chair, and the contributions of the different members read before this Section, I find few dealing with those portions of Australasia with which I am personally familiar, viz. :—Queensland, British New Guinea, and Western Australia.

After due consideration, therefore, I have chosen to invite your attention for an academic hour to a succinct account of the recent advances in our knowledge of the geology of the Western portion of this Continent, to the investigation of which my attention has been more immediately directed during the last decade.

In a broad and general way the geology of Western Australia offers many interesting points of analogy with that of South Africa and India.

In the present condition of our knowledge of the geology of the State, it is almost impossible to deal systematically with the various formations as a whole, for, owing to a variety of causes, geological inquiry up to the present has consisted merely of a series of unconnected observations, to the co-ordination of which we must look to the future ; nevertheless our observations have been so widely extended as to permit of certain broad generalisations.

Geologically the rocks of the State may, for the purpose of this address, be divided into three distinct groups, viz.:—

(I.) The crystalline, schistose, and metamorphic rocks, a group the members of which have certain features in common, occupy definite areas, and various lines of inquiry point to being of considerable geological antiquity, possibly of Archæan Age, though in the present condition of our knowledge I prefer to adopt the term Pre-Cambrian.

(II.) The sedimentary rocks which extend with many blanks from the Lower Cambrian to the most Recent ; and

(III.) The volcanic rocks which are so largely developed in the northern portion of this State.

I.—The Crystalline Schists and the Metamorphic Rocks.

The Pre-Cambrian crystalline schists, and metamorphic rocks constitute the principal mineral region of Western Australia, and so far as is at present known, the area occupied by these venerable beds is about two-thirds of the total superficial extent of the State, which is 975,920 square miles. As our knowledge advances, however, this estimate of the area occupied by the Pre-Cambrian rocks may be subject to some modification.

There are probably few parts of this continent which can boast of a finer development of these older rocks than Western Australia, and perhaps no more promising field can be found for their investigation.

Considerable interest in connection with these rocks centres, so far as petrographical questions are concerned, in the translation of both the igneous and sedimentary formations into crystalline schists. Observations in the field point to the possibility of the mechanical movements to which the rocks have been subjected having modified or obliterated structural features previously impressed upon them, and that they may contain formations belonging to different geological systems. Sections in the Nullagine District show those beds to be made up of cleaved conglomerates some of whose pebbles consist of a pre-existing conglomerate from an earlier series, of which no trace has yet been found. With a possible exception alluded to later on, it is important to note that this ancient metamorphosed sedimentary series, so abundantly represented in Western Australia, has yielded no fossils as yet.

If perhaps I dwell at a somewhat greater length upon these older rocks, it is that their economic importance has necessitated the attention of the Geological Survey, being up to the present, principally devoted to their investigation rather than to that of the strata lying uncomformably above them.

Time will hardly admit, though there is the inclination, of trespassing upon your time by affecting comparisons with the geology of similar areas of Pre-Cambrian rocks in other countries, nor discussing many of those theoretical questions arising out of the data which have been massed.

These older rocks have been studied in more or less detail in different localities throughout the State, distributed over fourteen degrees of latitude. They consist of rocks of very different types, many of them are in a crystalline condition, and form coarse crystalline schists and gneiss, which differ but little from granite and other rocks of like origin, as well as basic rocks, which have been more or less crushed, foliated, and completely converted into greenstone schists.

A very important feature of these basic schists is the presence among them of unfoliated rocks which sometimes occur in the form of lenticular belts of considerable extent, diabase, dolerite, diorite, epidiorite, pyroxenite, porphyrite, amphibolite, etc.

In some localities these basic rocks can be seen passing by scarcely perceptible gradations into hornblende schists, while in others are bands of magnetite schist, in the centre of some of which are large phacoidal-shaped masses of greenstone occurring in such a way as to indicate that the margins only of the masses have been ground down into schists.

Some of these older rocks are of sedimentary origin, and are practically unaltered ; others are quartz, mica schist, and granulites, whilst these represent the two extremes there are intermediate forms which link them together. The less altered members of these older rocks make their appearance in many portions of the State ; the rocks consist of a great variety of types of indurated slates, quartzites, and conglomerates, together with igneous rocks, some of which there are very good grounds for believing to have been originally lavas and ashes.

Many of these old crystalline rocks have been so altered as to possess characters which cannot be looked upon as original because many of them have lost, not only their individuality, but also their geological identities.

A remarkable and very noticeable feature of these older rocks in most localities in which they have been examined is those bands of laminated quartzites and jaspers (which often contain oxide of iron to such an extent as to warrant their being classed as iron ores). These extend as roughly parallel bands, sometimes several miles in length, in the form of attenuated lenses which, owing to their serrated ridges stand out in bold relief, thus acquiring a conspicuousness perhaps out of all proportion to their real stratigraphical importance. These beds vary from almost pure quartz through varieties of banded hornstone, jaspers of great beauty, to almost pure hematite.

In certain localities these jaspideous beds present a very brilliant appearance, due to the interlamination of red, white, and dark-coloured bands with intermediate varieties, the difference of colour being due to the occurrence of iron in the form of either limonite, haematite, or magnetite.

These bands are often intersected by numerous faults, which, in some districts, are of considerable economic importance, for it is along these fault lines, generally at right angles to the strike of the quartzites, that rich shoots of gold often occur. In some cases these iron-bearing jaspers attain a very great thickness, over 1,000ft., and have been very much plicated and contorted, whilst in places they have been faulted in a direction parallel to the strike. The fault fissures being often filled with a fault breccia of jasper recemented by secondary chalcedonic silica. In all cases these jaspers and quartzites are vertical or inclined at high angles. In many localities these quartzites and jaspers contain magnetite in such quantities to render the use of a compass in the vicinity almost impossible. These beds have been styled quartzites, a term implying that they are sedimentary ; they are, however, not of detrital origin, numerous sections in many of the fields show them passing by almost insensible gradations into the enclosing basic schists, the whole appearance suggesting a gradual replacement of the original rock along lines of maximum compression, a foliation by silicification, in other words they represent a case of metasomatosis on an extensive scale.

It may be of interest to note that these beds invariably occur in the basic schists, in intimate association with auriferous quartz reefs, and are at times themselves auriferous. In order that the present confusion arising through the want of a name to distinguish infiltration or metasomatic quartzites from indurated sandstone may be obviated, I hope some one may be able to suggest a convenient means of escape from possible civil war between the field man and the laboratory man to which the present unsatisfactory system of nomenclature rather tends.

In 1905 the various divisions of these older crystalline rocks as developed on the Norseman Goldfield, were carefully mapped and investigated, the salient features of which may be briefly summarised. The staple formation consists essentially of a series of highly inclined sedimentary rocks estimated to reach a thickness, making due allowance for repetition by folding, of about 800ft.

No argillaceous slates appear to occur in the Norseman district, though associated with the metamorphic sedimentary rocks is a bed of very coarse conglomerate. Some of these ancient sedimentary rocks appear to have been permeated by secondary silica and oxide of iron to such an extent as to form very conspicuous bands of laminated quartzites and jaspers, which make a pronounced feature of the field. Associated with the metamorphic sedimentary beds of Norseman are a series of interbedded igneous rocks, some of which are distinctly amygdaloid, and although most of their original characters have been almost entirely obliterated, there seems every reason to believe them to be ancient lava flows, which were poured out at practically the same geological period as the associated sediments. In addition to these undoubted lava flows, there are a series of diorites and epidiorites, which seem to be interbedded with the former in such a way as to suggest the possibility of their being intrusive sills and dykes. These igneous rocks have been subjected to considerable dynamical alteration, and in places appear as mica and chloride schists.

Another very important feature in the geological structure of Norseman is the occurrence of a large number of quartz porphyry dykes which traverse the eastern portion of the field in a general north-west and south-east direction. These acidic dykes vary much in appearance, colour, and texture, the crystallisation in some cases being such that the rocks look not unlike somewhat fine-grained indurated sandstone. These acidic dykes contain crystals of pyrites, and are occasionally slightly auriferous. These dykes in all probability form the apophyses of that large granite mass which lies to the east of Norseman. There are, in addition, a few isolated veins and dykes of dolerite, one of which is seen intersecting the quartz reef in one of the mines. The newest igneous rock on the field is the intrusive norite, which forms an east and west range, varying from a mile to half a mile wide, and which extends in an uninterrupted line to Mount Norcott, about twelve miles to the east, and for a considerable distance both east and west.

The earliest observer in this district, Mr. S. Goczel, indicates on his geological sketch map of the Auriferous Region of Western Australia the greenstones and allies of Norseman as being of Paleozoic Age, whilst the micaceous and talcose schists of the same district are referred to the Archæan.

The crystalline rocks of the type just described may be traced as far as the Kalgoorlie Goldfield, the wealth of which, coupled with the skill which directs both the mining and the metallurgical operations, have raised Western Australia to the front rank of mining countries in the British Empire.

As is well known, the productive area comprises a relatively small block of ground, which, by reason of the richness of the lodes by which it is riddled, has become known throughout the world as the "Golden Mile."

This area includes the well-known "Great Boulder," "Ivanhoe," "Horseshoe," "Perseverance," "Oroya-Brownhill," "Associated," and "Lake View Consols" mines. The deepest shaft at present is the Great Boulder, which has reached over 2,000ft., while the greatest depth to which the lodes have been followed is over 2,000ft. The country laid open by mining for investigation as judged by the number of drives and crosscuts amounts to several miles, whilst the rocks have been riddled with bore holes in all directions and angles, thus affording opportunities for the scientific study of many of the rocks in critical localities, and in their relation to the ore deposits, such as are hardly found in any other single mining field of the globe.

The geological structure of Kalgoorlie is not of that extreme simplicity which at one time had been anticipated. The staple formation consists as at Norseman, largely of certain schistose rocks, some of which are distinctly of sedimentary origin. The sedimentary beds are represented by rocks, which range from soft shales to jasperoid slates, grits to flinty quartzite, fine conglomerates or breccias to fairly coarse boulder conglomerate.

In intimate association with the sedimentary beds are a series of hornblendic rocks, but whether these occur in the form of lava flows or are intrusive is as yet by no means clear.

There are, however, in addition to these certain undoubtedly intrusive igneous rocks, sodafelsites and porphyrite.

Most of the rocks of Kalgoorlie appear to have been highly altered by dynamical causes, with an accompanying recrystallisation of their constituents ; many of them have been carefully analysed and microscopically investigated in the laboratory of the Geological Survey and the results made available. Time will not admit of detailed reference being made to the deductions to be drawn from these investigations, beyond the fact that the "lode formations," for which the field is famed, consist of a series of almost vertical banded schists of lenticular habit, and apparently owe their origin to the dynamo-metamorphisin of a plagioclase-augite rock. Many of these ore lenses are of great length, and in some cases of considerable breadth; at times however, the lateral continuity of the lenses is interrupted by overthrust and normal faults of very variable downthrow.

For a systematic study of the metasomatic history of the auriferous deposits, leading as such must do to the discovery of facts which will materially guide scientific mining, Kalgoorlie offers few, if any, rivals in Australia.

So far as observations have, however, at present been carried there do not appear to be any scientific reasons for believing that the mines of Kalgoorlie have by any means reached the limits of ore deposition, or that the lodes will not prove as a whole productive in depth.

The Pilbara district (lat. 21 degrees) affords better and more continuous sections than are generally to be met with in any of the other districts which have yet been examined; it thus reveals geological structures which are not to be found in the more southerly districts, and on this account serve to throw light upon obscure points in connection with the geology of other districts. These sections furnish very important evidence regarding the terrestrial movements to which these older rocks have been subjected. The Pilbara district contains very large areas of granite, granodiorite and gneiss, which, however, are not the oldest rocks. In every case where their relation to the schists can be observed along the margin, it is seen that these granites are everywhere intrusive, having gradually eaten its way into and partially absorbed them, and several sections may be noticed in which the granite sends out tongues and veins into them. One of the best localities in which the relation of the granite to the metamorphic rocks is at the Wodgina tinfield, which is situated on the headwaters of the Turner River about 24 miles from Port Hedland. The districts consist of a series of metamorphic sedimentary and bedded igneous rocks skirting the margin of an extensive granite mass, several hundred square miles in extent. These sedimentary auriferous rocks are pierced by a multitude of granite veins which in this district are of considerable economic importance by reason of the fact that they form matrices of tin and tantalite, for which Wodgina is noted. Near the tinfield is an instructive section showing a much older instrusive granite rock, which has been invaded by the much newer (though still old) tin-bearing granite. These acidic veins are made up of a coarse-grained rock composed of mica, quartz, felspar, and now and then tourmaline, and may be described as pegmatite, using the term in the sense in which it was applied by Delesse for any coarse-grained granitic rock containing mica, quartz, felspar, and tourmaline. No reference to these old granitic rocks would be complete without some mention being made of the large ice-like quartz reefs, which stand up to considerable altitudes above the surface like a wall, and which can in some cases be traced across country, with more or less interruption, for miles. They may be described as veins or dykes of pure silica, in some of the mine workings in two fields veins of this character are to be seen cutting across the auriferous quartz reefs. The question as to the relationship of these acid intrusive dykes of the type just mentioned and these quartz reefs has recently been attracting considerable attention, and there is a growing tendency to associate some quartz reefs genetically with pegmatite granite veins. In the Coolgardie Goldfield quartz reefs are often intimately associated with acidic dykes, and in some cases the latter gradually pass into pure quartz at their extremities. These acid dykes can be seen to pass by imperceptible gradations into the main mass of the granite at Coolgardie. Similar instances have been noticed in the Wodgina neighbourhood, and doubtless there are numerous other instances, but possibly they may have been overlooked, and their significance unappreciated.

Now a granite mass during the process of cooling gives rise to more acid pegmatite veins, and by further elimination of the bases pure quartz veins may result.

Various intermediate stages between granite and quartz veins have been noticed in Western Australia, and it is more than likely that many quartz veins are very probably intrusive rocks directly secreted from a cooling granite magma. Many pegmatitic granite veins contain tourmaline crystals as one of their essential constituents and many pure quartz veins in Western Australia contain tourmaline also.

Up to the present time, however, no observations have been made in this State with the object of discovering whether there are any of those structural and mineral changes induced in the enclosing rocks by the introduction of the quartz such as may often be observed consequent upon the injection of granitic veins. Observations upon this head, which are much to be desired, would have considerable scientific and even more important economic value.

In the southern portion of the State, the Darling Range, the Northampton District, etc., this fundamental complex is pierced by a much later series of basic dykes, where they sometimes preserve their dyke-like features across country without a break for miles. In the North-West district, however, they occur on a scale of magnificence as yet unknown in any other portion of Western Australia. Owing to the marked features which many of them exhibit these dykes can be readily followed across country, and in certain localities they are of considerable value in working out the details of the geological structures. A feature of significance is the faulting these later dykes have undergone since their injection and consolidation. In the Warrawoona field, an important North-West mining camp, these basic dykes traverse the centre of the auriferous zone almost at right angles to its general strike. The regular continuity of the system of dykes (which extend across country for 30 or 40 miles) has been interrupted in the vicinity of their intersection with the auriferous series, and they have undergone considerable movement since their injection. The peculiar dislocation and apparent displacement in short segments are probably due to a development of step-faulting in a manner not as yet fully understood. The dykes are apparently cut into curved and distorted segments and displaced along more or less vertical planes which have a general tendency to shift the separate portions bit by bit, in one direction, the dykes being dragged to the north-west of their course.

A very important feature in the geology of the Pilbara District is the evidence of great earth movements that affected the district.

In the neighbourhood of the picturesque Doolena Gorge, on the Coongan River, very impressive evidence of a powerful rupturing of the crust is to be seen, represented *inter alia,* by a line of dislocation, which has been proved to extend for nearly 100 miles. The large quartz reefs to which allusion has just been made are seen to be abruptly cut off by this powerful fault, which presents a steep vertical escarpment (unscaleable in places) often over 150ft. in height. At some distance north of this main fault an instance was observed (on the eastern bank of the Strelley River) of one of these large reefs, being not actually truncated, though subjected to deflection by a powerful thrust, exerted in a direction approximately parallel to its strike. In this instance the compression has been so great that this very reef, which is about 30ft. thick, was reduced to six to 10 inches, whilst the horizontal displacement reached about 100ft.

The quartz reefs of the district also afford evidence of overthrusting, contortion, etc., and many of them present features which seem to indicate that they have been wrenched apart by movement along shear planes. A very important instance of this is to be seen at the mining camp of Warrawoona, where a line of reef of a peculiar type traverses the field along a powerful dislocation, which has been followed for two and a half miles.

This dislocation occurs along a persistent reef, portions of which have been torn apart and shifted in segments, producing the peculiar kidney or damper-shaped lenses of quartz, which vary from a few inches to a foot or so in width. The interval between each lens of quartz fluctuates within very wide limits.

The walls of the country enclosing these lenses are scored with striae in the direction of the movement in a vertical direction, and the faces of the striations are often coated with fine films of gold. The abnormal richness, nearly 3ozs. per ton, of this type of auriferous reef has resulted in its being extensively prospected almost along the whole length, hence abundant opportunities are afforded of investigating its peculiarities, both on the surface and below ground.

The ancient sedimentary beds, which consist of highly siliceous rocks, dipping at varying angles to the north and east, consist of fine-grained flaggy quartzites, conglomerates, and quartz schist.

Some of the conglomerates still retain traces of their original character, though in others most of the pebbles have been flattened out and stretched almost beyond recognition.

The oldest series of basic dykes, by which they are traversed, have also been crushed and sheared, and are now represented by bands of schistose greenstones. The rocks are also intersected by certain other acidic dykes now represented by quartz-sericite schist, which may have originally been porphyries. One example from Warrawoona is a quartz sericite schist with "eyes" of a fairly soft mineral, originally a potash felspar, around which the fine foliation of the matrix sweeps in very graceful curves. When submitted to microscopic examination it is found that these porphyritic crystals present that peculiar peripheral granulation so characteristic of crystals and fragments which have been subject to intense crushing.

All the features, both of the rocks and the reefs, coupled with other evidence, clearly indicate the presence of a number of overthrust and normal faults, and point to a series of movements along lines parallel to that of the main trend of the dominant structural features of the district, which is north-west and south-east. The disruption of the newest series of basic dykes to which reference has been previously made, indicates that the enormous terrestrial stresses and strains continued in the same locality over a wide interval of geological time.

Traces of life may perhaps have existed in these old rocks of the north-west. Amongst the quartz schists which form the lofty serrated summit of the main axis of Warrawoona is a bed which here and there contains what at first glance appears to be fossil wood.

A characteristic specimen of this silicified wood (?) has a length of about 4½inches ; cross-sections of it are ellipsoidal in shape, the major axis being about ¾ and the minor axis about ⅝ of an inch in length.

Microscopical sections, both transverse and longitudinal, were prepared and submitted along with the specimens to Mr. Etheridge, of the Australian Museum, who, however, was unable to detect any trace of organic structure in them. It is, however, quite possible that some form of organic life existed at the time these beds were deposited, and that the marked changes which they have undergone obliterated all traces of organic structure.

II.—The Sedimentary Rocks.

The sedimentary rocks, etc., include the whole of the beds which lie between the ancient crystalline rocks and the more recent strata. In spite, however, of the extensive area occupied by the complex of crystalline schists, Cambrian fossils have been as yet noticed from only one locality in the far North of Western Australia.

Mr. E. T. Hardman, of the Geological Survey of Ireland, was the pioneer geological observer in the far North of Western Australia, and his researches carried out in the years 1883 and 1884 laid the foundation of our knowledge of the geology of the Kimberley District. This observer, however, obtained fossils from some limestones which have been referred to the Cambrian.

In 1891 Mr. H. P. Woodward made an extensive examination of the Kimberley District, and added considerably to the observations of Mr. Hardman.

Ten years later, in 1901, in company with Mr. Chas. G. Gibson, Assistant Geologist, I made a series of investigations in the King Leopold Plateau when searching for a reputed goldfield on the Carson River, between the 15th and 16th degrees of latitude.

In the latter part of 1905, and the early months of 1906, Dr. Jack visited Kimberley for the purpose of inquiring into the possibility of artesian water being obtained in the district.

Mr. Woodward revisited Kimberley in the winter of 1906, and examined the country between Mount Broome and the coast on the west, in the vicinity of Collier Bay, and obtained *inter alia* a trilobite from a dun-buff coloured limestone. The trilobite, which has just been submitted to Mr. Etheridge, appears to very closely resemble *Olenellus.*

Mr. Woodward describes these limestone beds as dipping at angles varying from 12 to 23 degrees to the south-west. The basal beds, consisting of limestone and conglomerate, contain fragments and boulders of the schistose and granitic rocks which unconformably underlie them. This observation is of importance in that, with the specific determination of the fossils he collected, light may be expected to be shed upon the age of the crystalline schists.

We thus have a good many details regarding the geology of this far north region, though as our knowledge has advanced it cannot be said that the tangled skein has yet been unravelled.

In the course of his investigations, Mr. Hardman gathered a suite of fossils which were critically examined by Mr. R. Etheridge and Mr. W. H. Foord and Dr. Henry Woodward.

Among the *disjecta membra* were the head and spine of a trilobite belonging to the characteristic Cambrian family, Olenellus Forresti and numerous pteropods, Salterella Hardmani, from a locality which, unfortunately, cannot now be identified. The discovery of the locality from which Olenellus was obtained by Mr. Hardman may be expected to go a long way towards setting at rest much that is at present puzzling regarding the geology of Kimberley.

Dr. Jack, writing in February of 1906, regarding the locality of Olenellus Forresti, says:—

> The fossils described by Mr. Foord in his Notes on the Palæontology of Western Australia (Geol. Mag., March and April, 1890),

> were collected by Hardman in 1883, and presented by him to the British Museum in 1886. Hardman's trip of 1883, described in his first report (1884), extended from Derby to the Leopold Range. Hardman's label on the trilobite in question was:—" River South of Base-line."
>
> There are two base-lines on Hardman's maps: (F9-EB) at Mt. Campbell (Lat. 18.13) (Long. 125.30), and the other (WE-EB) at the Hardman Range (Lat. 17.40) (Long. 128.50). If the *Olenellus* was collected in 1883, the base-line referred to must have been F9-EB since Hardman could not, in 1883, have mentioned a line which was not laid down till 1884. On the other hand, there is *no* river " South of Base-line " F9-EB within the limits of Hardman's work, unless Christmas Creek be meant.
>
> There *is* a " river " (Hardman, in Irish fashion, called all small watercourses "rivers") viz.: the Turner, south of Base-line WE-EB. It washes the south-west side of the Hardman Range, but a good deal farther from the range than Hardman's map gives it. The Base-line WE-EB could only be the one referred to on the supposition that Foord's information as to the date of the discovery was erroneous—that " 1883 " should read " 1884."
>
> *But* the limestone indicated in *this* case is classed by Hardman as the lower member of his Carboniferous formation, and I saw what is, no doubt, its continuation resting on a considerable thickness of beds of basalt, which lie on the upturned " Devonian " of the Albert Edward Range."
>
> *Olenellus* is Cambrian.
>
> Altogether, we are confronted by so many contradictory conditions that I am inclined to conclude that the fossil must be ignored as having come from a locality unidentifiable.

Despite the fact of poor localisation of Mr. Hardman's fossils, it may, I think, be taken for granted that Cambrian beds do occur somewhere in Kimberley about south latitude 18 degrees. The recent discovery of *Olenellus* and *Salterella* in the limestones of the Daly River, in the northern territory, by Messrs Brown and Basedow, is of considerable geological importance, indicating a somewhat wide distribution of Cambrian strata, and makes the solution of the Hardman puzzle almost imperative, and more especially so in the light of Mr. Woodward's recent discovery in the Napier Range.

By far the largest area of the Kimberley division is occupied by a formation which extends from Mount Hopeless, near Collier Bay via Mounts Hart, Broome, the Mueller, Saw, and Deception Ranges, Goose Hill, near Wyndham, to the South Australian border. These beds, which rest with a violent unconformity upon the crystalline schists, were provisionally referred by Mr. Hardman to the Devonian. Considerable confusion has arisen, as has recently been pointed out by Dr. Jack in a report on the Kimberley district now going through the press, in consequence of a discrepancy between the first and second reports of Mr. Hardman, in which he describes what recent observations have shown to be the same formation, first as Cambro-Silurian, or Cambrian, and later as Devonian.

These Devonian beds of Kimberley have yielded the following fossils : *Atrypa reticularis, Rhynchonella pugnus,* an *Orthoceras,* and two species of *Goniatites* and *Spirifera.*

A feature of interest and importance in connection with these beds is the evidence they afford of widespread contemporaneous volcanic activity. This was first noticed by Mr. E. T. Hardman in 1883 and 1884, who describes contemporaneous dolerites, volcanic breccias and tuffs. It has been suggested that some of the igneous rocks occur in the form of intrusive laccolites.

In the year 1901, Mr. Gibson and I had abundant opportunities of investigating these beds during six months spent in the exploration of what may be called the King Leopold Plateau. Our observations extended from Wyndham to Mount Hart, near Collier Bay; the Prince Regent and Glenelg Valleys—rendered almost classical by the researches of Sir George (then Lieutenant) Grey, more than 70 years ago—and as far north as Admiralty Gulf. The result of the investigations indicated that the staple formation was made up of a series of quartzites, sandstones, fine conglomerates and shales disposed in a series of broad anticlinal folds. These beds extend as one continuous formation from Mt. Cockburn to Mount Hart, a prominent summit on the King Leopold Range. Associated with the quartzites, etc., are a series of bedded and intrusive igneous rocks, the prevailing types being andesite, dolerite, and diabase. The individual characters of the different beds naturally present a large amount of variation; the rocks are sometimes amygdaloidal, and contain nodules of zeolites and agates. Beds of volcanic ash and breccia are common in certain localities.

In certain isolated portions of the district excellent sections are exposed, showing the intrusive nature of some of the igneous rocks; the sandstones are sometimes altered into hard compact quartzite, portions of which have been caught up in the body of the igneous rock. Other sections indicate quite clearly that the igneous rocks have, in some cases, found an easy passage along the bedding planes of the sedimentary rocks and evidently occur in the form of sills.

The lavas are traversed by almost vertical dykes of epidosite, which are traceable across country for long distances, whilst both the sedimentary and the igneous rocks are intersected by numerous segregation veins of quartz, some of considerable size and horizontal extent.

Mr. Hardman noticed during his explorations in 1883-4 the association of fossils of carboniferous affinities, with those characteristic of the Devonian rocks in the Kimberley beds. Dr. Jack noticed in 1906 a similar association of Devonian and Carboniferous fauna from the beds near Mount Pierre, and makes mention of the carboniferous limestone region, consisting partly of limestones of an older date, and remarks that either there are in the Mount Pierre region separable carboniferous and Devonian strata, or the same strata contain a Devono-carboniferous fauna. It is possible that this apparent admixture of Denovian and carboniferus fossils may have been brought about by post-carboniferous orogenic movements of which there is abundant evidence in different portions of the State.

Three field seasons spent by myself in the Pilbara Goldfield, situated in latitude 21 degrees south, afforded an excellent opportunity for examining a formation consisting of sandstones, grits, conglomerates, and limestones, some of which are magnesian, together with a series of lavas, ashes, and agglomerates of as yet unascertained thickness. In its lithological characters, its behaviour and general physical aspect it bears a very strong resemblance to the quartzites, etc., of the King Leopold Plateau, to which reference has just been made.

This formation, which has been designated the Nullagine series, has a very wide distribution in the North-West, and the associated volcanic beds occupy a large area of country in the southern portion of the district. The series, which presents a plateau-like appearance, certain of the harder beds standing out in bold relief, presenting mural faces at different levels, plays a very important part in the geology of the North-West, in addition to being of some economic value by reason of the fact that the basal conglomerate of the series has been worked for the gold it contains in two widely separated localities, viz :—Nullagine and Just-in-time.

The Nullagine beds have been followed from the Oakover River across the upper reaches of the Nullagine, Coongan, and Shaw Rivers, as far as the western boundary of the Pilbara Goldfields on the Yule River, near Cangan Pool, from which locality they can be followed without a break to the vicinity of Roebourne. The same series constitutes the Hamersley Range, which contains Mount Bruce, the highest summit in the State. The Nullagine beds are probably continuous as far south as the Ashburton River, where both flanks of the valley are formed by extensive beds of magnesian limestone, which may be continuous with those which I observed in 1905 in the recesses of the Hamersley Range.

Regarding the southern extension of the Nullagine series it may be noted that in a deep bore put down by the Government at Onslow, near the mouth of the Ashburton River, volcanic rocks identical with those in the former district were met with. It may thus be that these strata were pierced in the lower portion of the Onslow bore.

Undoubted Permo-carboniferous rocks are known to occupy a large area of country in the watersheds of the Gascoyne, the Minilya, and the Lyndon Rivers, hence the examination at present being undertaken of the country lying between Onslow and Lyndon should afford some valuable information as to the mutual relations of the

Permo-carboniferous and the Nullagine beds. So far as observations have at present been carried there seems to be a gradually ascending geological series as we proceed southwards. What I am inclined to regard as outliers of the Nullagine series occur in the Murchison Goldfield, near south Latitude 27 degrees. In 1904 Mr. Gibson mapped a considerable portion of the auriferous belt of the Murchison, and described a series of fine-grained volcanic ashes, lying almost horizontally on the granite of Mount Yagahong, about two miles south of the townsite of Gabanintha. The beds have evidently a wide extent in the Murchison. At the town of Cue, some distance to the south of Gabanintha, there is a horizontal dolerite sheet capping what is known as Cue Hill, and some little distance to the west on the lower ground are a few outliers of quartzite on a lower horizon. These quartzites evidently form part of a much more extensive formation of which they are but remnants left. There is very little doubt that these beds form part of the same series as the volcanic ashes at Gabanintha.

The igneous rocks associated with the series consist generally of acidic lavas. The great mass of the rocks consist of separate lava flows, each of no great thickness; some of the lavas are distinctly amygdaloidal, the cavities being filled with chalcedony.

Some of the finer-grained ashy beds differ very little in general appearance from many of the banded lavas with which they are associated.

Undoubted volcanic focii, from which these lavas emanated, occur in many parts of the districts, though they have been extinct long enough to allow the process of weathering to reduce them to mere stumps. There are also several acidic dykes which pierce both the sedimentary and the volcanic rocks, and these in all probability represent but another phase of that extraordinary volcanic activity which occurred in the northern portion of Western Australia during the Devonian period.

Considerable interest attaches to the Nullagine series by reason of the nature of the boulder beds at the base of the formation, for two important scientific reasons, viz. :—(*a.*) the occurrence of flattened and striated pebbles to which a glacial origin has been assigned ; and (*b.*) the nature of the gold and iron ore in the conglomerate.

The basal conglomerate of the series is made up of rounded, ellipsoidal, or subangular fragments of the older underlying series. Many of these often include pieces which reach a length of three or four feet. Some portions of the conglomerate contain flattened and striated pebbles of fine-grained sandstone and sandy shales, identical in character with those constituting the underlying strata. To these striated pebbles a glacial origin has been assigned by the late Mr. S. J. Becher, and subsequently by Professor David. The pebbles, however, seem to have had their striation induced prior to their taking part in the formation of the Nullagine series. The beds upon which the series rest, and to the denudation of which the boulders owe their origin, having, as has already been shown, been subject to intense mechanical deformation, it would only be natural to find some slickensided fragments and pebbles in newer rocks. Earth movements have caused the Nullagine beds to be thrown into a series of undulatory folds, but the deformation thus induced has not been of sufficient intensity to cause any striation of the Component pebbles.

Such mining operations as have been carried out in the auriferous conglomerate have been, up to the present, confined to relatively shallow depths along the outcrop ; the conglomerate is in part marked by the presence of large quantities of iron pyrites and its oxidation products. In the inoxidised portion the pyrites occur both as crystals, grains, and rounded or pebble-like forms. A certain interest attaches to the occurrence of these rounded pebbles and pellets of auriferous pyrites and hematite on account of the fact that they have been regarded as owing their shape to attrition, and that the gold and the iron are detrital, having been deposited with the pebbles of the conglomerate, as the result of all disintegration of the underlying auriferous rocks. The evidence respecting the origin of the gold in the Nullagine conglomerates indicates that it is a secondary and not an original constituent, and further, that the primary source of the gold is the quartz reefs which occur in the underlying formation.

From the known occurrence of auriferous quartz reefs, which furnished no small portion of the pebbles of certain portions of the deposit, it is of course quite conceivable that a certain amount of detrital gold forms part of the conglomerate, but there are obviously no means of ascertaining what is the proportion of primary to secondary gold.

There seems, however, good reason for believing that by far the greater bulk of the gold, together with the pyrites, was introduced by solution percolating down to the most porous portions of the conglomerate, the condition being facilitated by the downward inclination of the bed rock, and possibly accentuated in part by the folding which the strata have undergone.

One of the most important advances in Western Australian geology is the recognition of a glacial conglomerate in the marine carboniferous rocks, near the tropic of Capricorn.

The carboniferous rocks of the State cover a wide extent of country, and bid fair to become of considerable economic importance.

The occurrence of Carboniferous rocks would seem to have first been made known through Sir George (then Lieut.) Grey in the year 1841, in his journals of the two expeditions of discovery in

North-Western and Western Australia during the year 1837-9. There are four districts in which fossiliferous Carboniferous rocks are known in the State, viz.:—Kimberley, the Gascoyne, the Irwin River, and the Collie Districts.

The Carboniferous rocks of Kimberley have recently been investigated by Dr. Jack, when in quest for artesian water. This observer's work was carried out in the months of December and January during one of the most severe droughts experienced in the district, and with a temperature often reaching 114 degrees Fahrenheit. Despite the fact that the route followed in investigating these beds, has perforce to be governed by considerations of grass and water, our knowledge of the Carboniferous rocks of Kimberley has been greatly extended. The formation is divisible into a lower or limestone series (in which limestone predominates) and an upper sandstone series (made up largely of sandstones and other sedimentary beds). The two series have been seen to succeed one another conformably in the Haughton Range, south latitude 19 S. and East Long. 127 E. Both series have yielded an assemblage of purely Carboniferous fossils:—*Lepidodendron, sp.; Stigmaria,* sp.; *Stromatopora concentrica* (?) *Stromatopora placenta, sp.; Pachypora tumida; Zaphrentis, sp.; Syringopora* sp. ; *Actinocrinus,* sp. ; *Platycrinus,* sp. ; *Poteriocrinus crassus,* Miller; *Pentremites,* sp.; *Serpula; Spirobis,* sp.; *Fenestella plebeia* (*antiqua,*) McCoy ; *Productus, giganteous ; Produstus longispinus; Productus semireticulatus ; Chonetes,* sp. *; Chonetes Hardrensis ; Discina ; Orthis resupinata ; Strophalosia Clarkei,* Eth. fils ; *Rhynchonella pugnus ; Rhynchonella pleurodon ; Rhynchonella cuboides ; Orthotetes crenistria,* Phillips ; *Streptorhynchus crenistria ; Terebratula hastata* (?) *; Terebratula sacculus* (?) *Pleurotomaria,* sp. *; Toxonema,* small sp. *; Natica,* sp. *; Ceriopora,* sp. *; Chaetetes tumidus ; Stenopora Tasmaniensis ; Cyathophyllum,* sp. *; Cyathophyllum virgatum ; Cyathophyllum depressum ; Lithodendron affine.*

So far as observations on the Kimberley Carboniferous rocks have been carried, no boulder beds have yet been recognised, though in view of the occurrence of glacial conglomerates in India within 18 degrees of the Equator their presence in Kimberley would cause little surprise. The necessity for a further more or less detailed geological examination of a portion of the Kimberley district is at the present moment under consideration by the Government, and the solution of the many economic questions involved in the stratigraphical research which such an investigation entails is of no less importance to the community than the purely scientific results which of necessity follow.

The Gascoyne beds cover a very large area between the 22nd and the 26th parallels of South Latitude, and excellent sections of them may be seen in the valleys of the Wooramel, Gascoyne, Lyons, Minilya, and Lyndon Rivers. Like their representatives in Kimberley, the strata are divisible into an upper or sandstone and a lower or limestone series. The sandstone series, which is seen resting comformably upon the limestone, is well exposed in the Carandibby, Kennedy, and the Moogooloo Ranges, making a bold outcrop of almost 200 miles in length. The beds forming these ranges were, until quite recently, regarded as of Mesozoic Age. The discovery, however, of *Spirifera, Athyris* (?) *Productus,* and *Strophalosia* in the Kennedy Range, near Trig. Station K 37, on the northern bank of the Gascoyne River, definitely sets at rest the conflicting views until quite recently held regarding their position in the geological time scale.

The country to the east of the Kennedy Range is underlaid by fossiliferous beds of the limestone series, associated with which is the glacial boulder bed.

This bed, which forms a valuable stratigraphical horizon, has been traced across country for a distance of about sixty or seventy miles.

At the most southerly locality at which the boulder bed has been detected in Wooramel Valley, the boulders are of very large size, and is composed of rocks identical in character with those forming the older underlying rocks to the east, *e.g.,* granite and other crystalline and metamorphic rocks.

Some distance northward on the Wyndham River is a boulder bed in the limestone series. The bed, which at this spot attains no greater thickness than three feet, is crowded with boulders and pebbles of granite and crystalline rocks embodied in a calcareous fossiliferous matrix ; a photograph of a specimen of which contains fragments of *Spirifera Productus* and *Poyzoa,* in addition to *Aviculopecten tenuicollis,* will be found in the Annual Report of the Geological Survey for 1900. The pebbles and boulders have a large proportion of smooth and polished faces. The flats in the neighbourhood are covered with boulders and blocks of crystalline rocks evidently derived from the weathering *in situ* of the conglomerate which has a dip of about three degrees to the south-west. In the bed of the Wyndham River beds of flaggy sandy limestone are to be observed passing beneath the boulder beds indicating what is perfectly obvious from numerous sections that the glacial conglomerate does not lie quite at the base of the Carboniferous rocks.

Associated with the boulder beds of the Wyndham River are the following fossils :—*Hexagonella dendroidea,* Hudlestone sp. ; *Pleurophyllum Australe,* Hinde ; fragments of *Crinoid* stems, and *Polyzoa ; Spirifera Musakheylensis,* Davidson ; *Spirifera Hardmani,* Foord ; *Spirifera lata,* McCoy ; *Retcularia lineata,* Martin sp. ; *Athyris Maccleayana,* Eth. fil. ; *Chonetes Pratti,* Davidson ; *Productus* (cf *Pteuni-straitus,* Foord).

Northwards from the Wyndham River the *débris* of the boulder bed makes its appearance in great force. The flaggy sandstones immediately underlying it are covered with large boulders of crystalline rocks. Near Barragooda Pool, on the Arthur River, a thick bed of limestone directly overlies the boulder bed. This limestone has yielded the following fossils :—*Evactinoporo crucialis,* Hudleston ; *Rhombopora tenuis,* Hinde ; *Athyris Macleayand* Eth. fil Var. ; *Productus semireticulatus,* Martin ; *Aulos-teges,* sp. nov. ; *Dillasma,* sp. ind.

A few miles to the north of this, near Trig. Station K. 34, the Carboniferous beds are faulted against the older crystalline rocks which, in this locality, consist of quartz and mica schists, associated with either dykes or sills of porphyry.

In the southern branch of the Minilya River, near Trig. Station K. 49, the boulder bed is seen overlying beds of limestone and shale. The *débris* of the boulder bed consists of a heterogeneous collection of all sorts of crystalline and metamorphic rocks, and contains numerous ice-scratched pebbles ; photographs of several typical examples appear as Plate IV. of the Annual Report of the Geological Survey for 1900.

It may be mentioned in this place that in a deep bore put down by the Government at Pelican Hill, near Carnarvon, that these Carboniferous or Permo-carboniferous beds were met with beneath fossiliferous Mesozoic rocks at 1,406ft., and continued to 3,011ft., the present depth of the bore. The Carboniferous strata are represented by calcareous shales and limestone. The cores from the bore have yielded *Spirifera, Aviculopecten, Anthracoptera,* and *Favosites.* The bore, however, which did not pierce the whole thickness of the Carboniferous rocks gave no signs of the boulder bed. From the few salient features pointed out it appears quite clear that the glacial conglomerate is associated and interbedded with the fossiliferous limestones low down in the Carboniferous series as developed in this part of Australasia.

In the year 1897 I made a traverse up the Murchison valley in an exceptionally dry season, which seriously interfered with geological investigation, and at a point in the bed of the river, about 100 miles south of the boulder bed last mentioned, a conglomerate and breccia composed of angular fragments of a quasi-vitreous quartzite dipping at a low angle to the east was met with ; the base of the conglomerate was not visible anywhere, the most important and significant feature in this section is the fact that many of the pebbles were covered with scratches, not unlike slickensides.

A few yards lower down the river are a few beds of cross-bedded sandstones and fine conglomerates dipping east at an angle of about 20 degrees. One of the beds has been scored to such a degree as to produce surfaces as smooth and polished as plate glass.

The question arises, is this portion of a glaciated pavement, or is it due to faulting ? If the latter, the faulting is nearly horizontal. Some distance further up the river, near the Forty Mile crossing and water reserve 1005, the sedimentary beds are inter stratified with coarse conglomerates or boulder beds; the boulders are principally quartz, though pebbles of sandstone and granite occur. I detected no scratched boulders in this section, though circumstances did not admit of any detailed search being made. The important point in connection with these conglomerates containing the scratched boulders is that they form part of what is at present believed to be the southern extension of the Carboniferous series of the Gascoyne, and form a connecting link between the latter and the Irwin River series, to which reference will be made later.

Beneath the Jurassic rocks of the Champion Bay District and in the valley of the Irwin River and its tributaries is a fairly extensive development of Carboniferous and Permo-carboniferous beds In this district, as in Kimberley, it is possible to divide the strata into two distinct series, viz., the lower, or limestone, and the upper, or sandstone series.

Beneath the Irwin River coal seams are a calcareous shale and limestones, yielding a series of fossils, which have been carefully examined and described by Mr. Etheridge, of the Australian Museum, and will shortly appear as one of the Bulletins of the Geological Survey of Western Australia. The following fossils occur in these beds :—

Nubecularia, Stephensi, How ; *Pleurophyllum Australe,* Hinde; *Fenetella fossula,* Lons. ; *Dielasma,* sp. ; *Seminula subtilita,* Hall ; *Spirifera,* sp. ; *Reticularia lineata,* Martin ; *Productus semireticulatis,* Martin ; *Productus tenuis-triatus,* var Foord Eth. fil. ;*Productus undatus,* Defrance ; *Productus subquadratus,* Morris(?) ; *Chonetes Pratti,* Dav. ; *Aviculopecten Sprenti,* Johnston ; *Conocardium,* sp. Brom. ; *Stutchburia,* sp. Eth. fil. ; *Bellerophon costatus,* J. de C. Spy.

Gastrioceras Jacksoni, sp. nov. (the largest goniatite yet found in Australia, and of an entirely different type to the incomplete forms so far described).

The facies of these fossils is more akin to the Carboniferous than the higher Permo-carboniferous, and only four species are with certainty identical with those found in the Permo-Carboniferous rocks of Eastern Australia, viz. :—*Nubecularia, Productus subquadratus, Fenestella fossula,* and *Aviculopecten Sprenti.*

Associated with the marine series is a boulder bed, the *débris* of which strew the surface for a considerable distance, but there has as yet been no opportunity of investigating these beds in any detail. So far I have seen no striated pebbles among the boulders.

About 25 miles lower down the river, in the vicinity of Mingenew, and close to the railway line, are a series of ferruginous sandstones, on a higher horizon than the limestones, which remind one very forcibly of the sandstone series as developed in the Kennedy Range of the Gascoyne River. These beds have yielded the following fossils :—

Dielasma nobilis, sp. nov. ; *Dielasma hastata,* Dana ; *Spirifera,* sp. ind. ; *Spirifera avicula,* E. B. Spy ; *Cyrtina carbonaria,* var. Australasica, Eth. fil. ; *Cleiothyris Macleayana,* Eth. fil. ; *Productus Subquadratus,* Morris ; *Productus brachythoerus,* E. B. Spy ; *Chonetes,* sp. ind. *Deltopecten subquinquelineatus,* McCoy ; *Modiola* (?), sp. ind. ; *Myalina* (?) *Mingenewensis,* sp. nov. ; *Fenestella* or *Proloretepora.*

On the whole, it seems that the aspect of the fossils is that of the Permo Carboniferous of New South Wales.

It thus seems that there are in the Irwin River valleys beds of Carboniferous and Permo Carboniferous Age, and that the coal seams may possibly be the equivalents of the Greta Coal Measures of New South Wales.

The Collie River beds, which attain a thickness of a little over 2,000ft., are of considerable economic importance by reason of the fact that they contain coal seams to a total thickness of about 137ft., and are of some scientific interest in their relation to the important question of the distribution of the *Glossopteris* flora.

The Collie River coal field lies to the east of Bunbury and south of Perth, north-western edge of the tableland which succeeds the coastal plain. The field itself is traversed by the Collie River at an altitude of about 600ft. above the level of the sea. The area occupied by the Collie River coal measures is approximately 500 square miles. The beds consist of alternations of shales, sandstones, and grits, which rest directly upon granite schist and other crystalline rocks. The boundary of the field is, with one local exception, everywhere defined by faults ; on the south-western side of the field the boundary fault has been estimated to have a down throw to the north-east of at least 2,000ft.

There are several coal seams in the field of variable thickness, they consist in descending order of Cardiff No. 1, seam 9ft. to 12ft. thick.

Cardiff No. 2 or Boulder Seam, 7 feet thick.
Collie Burn No. 1 Seam, 9 feet thick.
Collie Burn No. 2 Seam, 6 feet to 7 feet 10 inches thick.
Coal (no name), 8 feet thick.
Proprietary No. 1 Seam, 4 to 8 feet thick.
Proprietary No. 2 Seam, 5 feet to 7 feet 6 inches thick.
Wallsend Seam, 9 to 17 feet thick.

The coal seams are hydrous, semi-bituminous, non-caking coals, which approach very closely to lignite in some parts; between the various varieties the differences are only of degree for there are no distinctive characters which would find universal application. Owing to the conditions of deposition the coals naturally vary in character, and in places pass insensibly through forms containing a large proportion of earthy matter into carboniferous shales.

The question of the precise geological age of the Collie River beds is one about which there has been, and still is, considerable divergence of opinion.

In the year 1891, Mr. H. P. Woodward, the Government Geologist, assigned an early Mesozoic Age to the beds, basing his determinations principally upon the physical aspect of the field, and the chemical composition of the coals.

A little later some fossils were submitted to the late Mr. R. Etheridge, sen., who detected *Glossopteris* or *Neoggerthia,* and concluded that the beds were Permo Carboniferous.

In 1894, Mr. Woodward, basing his opinion upon the results of Mr. Etheridge's determination, referred the beds to the Upper Carboniferous.

In 1897, Mr. E. F. Pittman, Government Geologist, New South Wales, visited Western Australia, and in a report, referred the strata to the Mesozoic, on the strength of Mr. Etheridge's (jun.) doubtful recognition of *Sagenopteris.*

Upon a geological map accompanying a report by myself, published in 1898, the age of the beds was defined as uncertain.

In 1898, Sir Frederick McCoy reported the discovery of *Glossopteris Browniana* in some fossils sent to him by the Premier of the State, and stated that the beds were of "the exact geological age of the great coal fields of Newcastle, New South Wales." I may add, however, that these fossils were not collected by, nor were they ever seen by, any member of the geological staff.

Mr. R. Etheridge, jun., in his "Notes to accompany a miscellaneous collection of Western Australian fossils," submitted to him by myself in 1903, recognised undoubted *Glossopteris* in a good state of preservation, from the Moira Colliery, and constrained him to support the age assigned to the Collie River beds by his father, viz., Permo-Carboniferous. Mr. Etheridge carefully examined the *Sagenopteris* (?) obtained by Mr. Pittman, and in the same report abandons his previous determination, and now looks upon it as *Glossopteris.*

In 1904 Dr. Jack received a Commission from His Excellency the Governor to fully investigate all aspects of the Collie coal industry, including *inter alia* geological conditions. Accompanying the Commissioner's Report is an excellent geological map and longitudinal section ; upon the former the age of the Collie River beds is set down as undetermined. Dr. Jack in his report says:—

> The evidence bearing on the age of the Coalfield is at best inconclusive. High authorities have indeed expressed the opinion that it was of Palæozoic Age—Carboniferous, or Permo-Carboniferous—but all these opinions are founded exclusively upon the presence of the form *Glossopteris,* which is now known to range from Carboniferous to late Cretaceous. The shales are coarse-grained and incoherent, and badly adapted for the preservation of plant remains.

Dr. Jack draws attention to the fact that the various beds in the series are less coherent than is customary among the Carboniferous or Permo-Carboniferous formations of Europe, Africa, and Australia, and concludes :—

> In a somewhat wide experience I have seen nothing which the Collie Coal Measures, coal seams included, so much resemble as the Oligocene Coal Measures of Croatia. While eagerly looking forward to the production of further evidence and open to conviction, I am at present inclined to believe that the Collie Coalfield will turn out to be possibly of Cretaceous Age, newer than the Coalfields of Ipswich and Burrum of Queensland.

The next and perhaps most important evidence bearing upon the controverted question is contained in some "Notes on fossils from the Collie Coalfield, Western Australia," in the "Collection of the National Museum, Melbourne," by Mr. F. Chapman, the Palæontologist to the Natural History Museum, Melbourne, just about to be printed as one of the Bulletins of the Geological Survey of Western Australia.

This writer recognised the plants :—*Glossopteris browniana ; Glossopteris browniana var indica; Glossopteris browniana var communis ; Glossopteris browniana var angustifolia ; Glossopteris browniana gangamopteroides.*

And in the associated sandstones the following Foraminifera:—*Endothyra ; Valvulina plicata* (U. Carb. List, England) ; *Bulimina* (Permo-Carboniferous, N.S.W.) ; *Truncatulina haidingeri* (Permo-Carb., N.S.W.) ; *Pulvinulina exigua.*

The *Valvulina* of Collie, though very much dwarfed, is essentially a Carboniferous form whilst the other species Mr. Chapman detected and described point in a general way to the Palæozoic Age of the series.

Mr. Howchin pointed out in 1893, in his "Census of the Fossil Foraminifera of Australia," that the Australian Palæozoic foraminifera show a closer affinity with the Permian fauna of the Northern hemisphere than the Palæozoic.

In view of all the evidence at present to be deduced from the plant remains and the marine organisms in the beds associated with the Collie coal seams, despite the nature of the coal and the physical characteristics of the basin, I am constrained to admit that a Permo-Carboniferous Age of the series presents the strongest claims to acceptance. I make no excuse for the fact that my present views on this much debated question are not those I previously held, but our most cherished opinions, like everything else, must yield to that stern logician—fact.

Jurassic rocks have been found up to the present in only one district—that of Champion Bay, near Geraldton; but the beds have not been investigated in any detail by the Survey, hence our information about them is at the best somewhat meagre.

Mr. Crick, of the British Museum, in a paper on "A Collection of Jurassic Cephalopoda, from Western Australia," records *Ammonites* (*Perisphincts*) *Championensis* from Cape Riche, to the East of Albany, and naturally claims a Jurassic Age for the beds.

In 1898 I visited Cape Riche. The beds consist of sandy limestones, which extend between Cape Riche and Warriup, and are fossiliferous. The Cape Riche beds have yielded :—Impressions of a Cycadaceous leaf (?) *Hemiaster,* sp. ; *Pectunculus, near P. flabellatus ;* Ten. Woods, internal casts of *Cytherea, Arca, Lima, Mactra, Amusium* and *Voluta,* in addition to *Venus,* near *V. Voseotineta,* Baird.

The Warriup beds have yielded:—*Cardium,* sp. ; *Cardium hemicardium,* Linn ; *Trochus personatus* (?) Phil. and *Arca reticulata,* G.M. These strata would therefore seem to be either recent or very young Tertiary. Even assuming that the Cape Riche series turn out on further investigation to be Secondary, I do not think the Jurassic can put in any claim for recognition. I am, therefore, inclined to think that Mr. Crick's Ammonite recorded from Cape Riche has been wrongly localised, and really came from Champion Bay.

The Champion Bay Jurassic beds cover a fairly large area of country to the south in the neighbourhood of the coast line; they are seen to rest with a violent unconformity on the Carboniferous rocks of the Irwin River valley. They also probably extend northwards, for in the deep bore near Carnarvon strata high up in the Mesozoic series have been recognised, between 1,200 and 1,500 feet.

The Champion Bay beds consist of oolitic limestones, clays, sandstones, grits, and conglomerates. Fossils are abundant, and they include a considerable number of Cephalopoda:—*Belemnites,* sp. ; *Nautilus perornatus,* sp. nov. ; *Ammonites* (*Dorsetensia*) *Clarkei,* sp. nov. ; *Ammonites* (*Stephanoceras*) *Australe,* sp. nov. ; *Ammonites* (*Sphaeroceras*) *Woodwardi,* sp. nov. : *Ammonites* (*Sphaeroceras*) *semiornatus,* sp. nov. ; *Ammonites* (*Perisphinctes*) *Championensis,* sp. nov. ; *Ammonites* (*Perisphinctes*) *robinginosus,* sp. nov. There have also been obtained:—*Trigonia Moorei, Lycett, Myacitus Sandfordii,* Moore ; *Lima,* sp. ; *Lima* allied to *L. pectiniformiss,* Gold ; *Cucullaea semi-striata,* Moore ; *Pleuromya, Astarte Cliftoni,* Moore ; *Cresslya,* sp. ; *Gryphaea,* sp. ; *Mytilus* allied to *M. Cygerensis,* D'Orb ; *Pecten frontalis,* Dumortier.

No estimate can as yet be made of the thickness of these Jurassic beds; they have, however, been pierced by four bore holes in the Champion Bay district, the deepest being at Dongara. This bore was sunk for the purpose of the delimitation of the seaward extension of the Irwin River coal measures, which there are good grounds for believing to lie beneath the Mesozoic beds. The bore attained a depth of 2,111 feet when operations were stopped owing to the capabilities of the boring plant being exhausted without the base of the Jurassic rocks having been reached. There are thus over 2,000 feet of these beds in this locality.

The recognition by Mr. W. D. Campbell of the remnants of an extensive dolomitic limestone formation at an altitude of about 900 feet above the level of the sea at Norseman, and distant about 100 miles due North from the coast at Esperance Bay (Long. 122 degrees East) containing fossils of either late Tertiary or Recent Age is, perhaps, next to the Carboniferous Glacial beds, one of the most important of the recent advances in our knowledge of the younger geological formations.

Two small outliers of this formation occur on the western bank of Lake Cowan and four near Lake Dundas. The beds, which in the vicinity of Norseman occupy but a very small area, consist principally of a dolomitic limestone, with several siliceous bands. These beds contain species of *Turitella,* allied to *T. terebra ; Pecten, Cardium* (or *Cardita*) *Magellania,* and fragments of *Polyzoa.* These discoveries are of considerable importance, and must be thoroughly examined some day, as they involve a whole series of important conclusions which depend upon the age of the fossils the beds contain.

At Balladonia, many miles to the east and in what is known as the Eucla limestone plateau, the flesh coloured limestones have yielded:—A Pecten, allied to *Chlamys asperimus,* Lamck ; near Madoura Station a shell aglomerate yielded *Venus peronii* var *conularis,* Lamck ; and *Tapes,* probably *T. Avaneosus,* Phillipsi, a living species. These fossils seem to indicate a deposit of comparatively recent age.

Entering the State at its eastern frontier in the Nullabor Plains, and extending without any interruption as far as Israelite Bay, is very large development of strata of Recent and Tertiary Age. These strata consist of flesh-coloured limestones associated with sandy porous beds, into which the rainfall is rapidly absorbed and discharged seawards in the form of fresh water springs, and are the western extension of the beds pierced in the five bores in South Australia.

These beds form what is known as the Premier Downs. An immense limestone plateau extending from Goddard's Creek (E. Long. 124 degrees) to the South Australian frontier, terminating abruptly along its southern border by a conspicuous escarpment

400 feet high in some places. The limestone plateau extends for miles into the interior, and the average altitude (so far as can be ascertained) of the inland margin is about 1,000 feet above sea level.

The bore nearest the Western Australian frontier is at Albalakaroo, on or near the telegraph line at about 45 miles east of Eucla. This bore attained a total depth of 1,084 feet, and bottomed on granite at 1,073 feet, after passing through (in descending order) 565 feet of (Eucla) limestone, 426 feet of clay (?shale), and 82 feet of a "hard rock," which those in charge of the operations could not determine.

Two bores have been sunk by the Western Australian Government near Madura. No. 1 bore was put down at a point 110 feet above sea level, and distant 30 chains south of the Eucla limestone escarpment, which is 350 feet high. The bore was carried down to a total depth of 2,041 feet, and passed (in descending order) through about 766 feet of limestone, underlaid by alterations of clay shale, sometimes Glauconitic dolomitic limestone. The bore ended in a soft mudstone. The second or No. 2 bore was situated 30 miles to the north of No. 1, on the limestone plateau, and about 300 feet above the level of No. 1. It was carried down to a depth of 412 feet, and passed through nothing else but limestone—the Eucla limestone. The sequence of strata in the Western Australian bores coincides in its essential particulars with that indicated by the South Australian bores, and there can be very little doubt as to identity of the two series of beds whatever may be their age.

Laterite.—No mention of the recent advances in Western Australian geology would be complete without some reference to that extensive development of residual deposits which have been found over the whole length and breadth of the State.

The term laterite has been officially adopted, though in a somewhat more extended sense than its original application, for all the deposits resulting from the decomposition and reconsolidation of rocks *in situ.*

The laterites of Western Australia consist largely of hydrated oxide of iron and alumina, producing on the one hand deposits of excellent iron ore and on the other bauxite. In some parts of the State the deposition of secondary silica in the lateritic deposits produces what are practically quartzites; these, by an increase in the ferruginous colouring matter, pass into a jasperoid form of laterite. There are thus three forms of these laterites—an aluminous, a ferruginous, and a siliceous—the composition being liable to vary considerably over a small area, it being largely governed by the nature of the underlying rocks.

The structure is sometimes massive and almost homogeneous, but is more frequently pisolitic and nodular, in which case the concretions are richer than the interstitial matter.

The lateritic deposits naturally vary in their lithological characters. They are often very porous and weather into caverns and cavities of all sizes. The surface of the rock is often covered with a glaze of hydrated oxide of iron. When freshly broken the rock presents a mottled appearance owing to the different shades of brown, yellow, and red. The rock passes gradually into the underlying rocks without any sharp line of demarcation. That ferruginous and siliceous laterites are more commonly met with is due to the fact that deposits of this type are better able to resist disintegrating influences than the softer varieties; they thus not only remain themselves, but act as a protecting cover for the rocks beneath.

Mr. J. Beete Jukes, writing in 1850, in his almost classic "Sketch of the Physical Structure of Australia," mentions the occurrence of these lateritic deposits as seen by him in the country between Perth and York. He says :—

> For a few feet below the surface the rock was a singular concretionary ferruginous compound which looked like a clay or sandstone that, being highly ferruginous, had formed itself into a mass of small balls and irregular concretions of a black oxide of iron or hematite. Below this ironstone (which is its name in the Colony) wherever the rock was exposed it appeared for many miles to be granite or some granitic compound.

In another place he mentions as occurring in one of the lateral valleys of the Swan River—

> A thin capping of ironstone forming a line of small crags.

In 1861 the late Mr. F. T. Gregory gives in his paper "On the Geology of a part of Western Australia," an account of this lateritic deposit capping, the Darling Range, and claims for it a Devonian Age. This observer mentions the important fact that the deposit blends gradually with the upper surface of the granite, and states that it would seem to owe its origin to the decomposition of the granite *in situ.*

The Rev. W. B. Clarke, in his "Sedimentary Formations of New South Wales," remarks :—

> Mr. F. T. Gregory indicated on his map and in his report the existence of Devonian Rocks near York, and in other parts of that Colony. Having examined the rocks so indicated, I can only state my belief that they have no pretension to any such antiquity and are probably mere collections of loose granitic matter, and other drift cemented by ferruginous paste, which has since become transmuted into concretionary nodules and hematite. There are also pebbles of trap, much decomposed in the so-called Devonian. They may be perhaps more properly considered as representing the Laterite of India.

It is on these historical grounds that Laterite has been adopted in Western Australia as the name for these residual deposits rather than the term Saprolite, which American writers have suggested.

The various reports of the Geological Survey contain numerous descriptions of these lateritic deposits, and are often accompanied by analyses.

These analyses show variations in alumina from 7.52 to 44.66 per cent. ; ferric oxide, 10.02 to 88.23 per cent.; silica, 1.53 to 23.26 per cent. ; combined water, 8.10 to 26.44 per cent. ; and oxide of titanium, .59 to 3.10 per cent.

A recent analysis of a ferruginous laterite from Comet Vale (North Coolgardie) is of interest

On account of the high percentage of chromium, mostly in the form of a hydrate readily soluble in hydrochloric acid, the balance being present in the form of chromite.

The analysis gave 79.01 per cent. of ferric oxide, 5.30 per cent. of chromic oxide, 3.14 per cent. of silica, and of water 12.35 per cent. Some of the laterites have proved to be more than appreciably auriferous.

In the southern portion of the State where the rainfall is greatest, the lateritic deposits support an abundant vegetation. The well-known karri and jarrah growing in all their splendour thereon. In fact the mapping of the lateritic deposits of this portion of the State would define the areas over which both karri and jarrah occur.

Elsewhere in the State the laterites support but a scanty vegetation.

So far as our observations have been extended the laterites, for the reason previously given, occur as disconnected outliers, which once formed part of a continuous deposit. It is difficult to escape the conviction that since they were deposited, a considerable time may have elapsed, hence the laterites may be of some geological antiquity of which possibly the thickness and the state of consolidation may be some measure.

We have, however, as yet, little authentic evidence on this point, though it may be mentioned that a bore put down at Coolgardie, on Reserve No. 23, certain plant remains were found in a deposit containing what is evidently the detritus of the lateritic beds. These plant remains have, on examination, been held to belong to the *Eucalypti.* McCoy has described definite eucalyptus foliage from the older gold drifts in Victoria, whilst Ettinghausen describes several species from the Upper Tertiaries of New South Wales and deep lead in the New England Tinfield.

On this evidence, therefore, the laterites seem to be of earlier age than the Tertiary, though there is but little doubt that lateritic deposits are forming at the present time.

III.—Volcanic Rocks.

Volcanic rocks have played an important part in the geological history of Western Australia, and the evidences of this igneous activity are to be found in the form of lava flows, ash beds, breccias, dykes, stills, etc., which make a prominent feature in certain portions of the State.

Many writers and observers, it must be noted with regret, treat volcanic rocks in such a fashion as to suggest that they constitute a more or less meaningless interpolation in geological history, and I have no desire to be included in the same category.

There are, so far as is at present known, three distinct periods in which Western Australia has been the scene of igneous activity of more or less intensity. These periods are :—

(*a.*) In Pre-Cambrian time, prior to the deposition of the beds containing the Olenellus fauna. These old igneous rocks are of importance in the part they appear to have played in connection with the formation of the ore deposits of the State. These have been more or less fully described in the opening portions of this address.

(*b.*) A period commencing early in the Nullagine (Devonian) time, but ceasing before the Carboniferous. The interstratification of lavas and ashes with the sandstones and conglomerates point to subaqueous eruptions, though from the amygdaloidal nature of many of the lavas, the bulk of these volcanic rocks must, I think, be sub-aerial. Several of the focii from which the lavas, etc., emanated, have been noticed. The magnificent series of basic dykes of the North-West and elsewhere, to which reference has already been made, suggest to one who has examined the Devonian Volcanic Series, that fissure eruptions, of which these dykes may form part, have been in some way responsible for the wide extent of the lava flows, which cover some hundreds of square miles.

(*c.*) After the deposition of the Jurassic Beds, and believed to be of Tertiary Age, they consist of basic lavas and ashes, which occur in great force in the Kimberley District.

In the Ord and Bow River valleys these lavas appear to have levelled up the depressions formed therein (except certain knife edge ridges of the older rocks, which still protrude above the level) and in places rest upon the Devonian Volcanic plateau. On the Behn River, just above what is known as the "Gorge," Dr. Jack noted a dome or "pug" of basalt, which apparently formed the focus from which some of these lavas issued.

At Bunbury, and one or two points on the coast round the south-west corner of the State, bedded columnar basalts occur. Over large areas, and far into the interior, numerous volcanic ejectmenta, in the form of obsidian bombs occur, and were probably derived from volcanoes of which no trace has yet been found, it is quite possible they may owe their origin to that volcanic region which skirts the northern coast of Australia.

The geological age of these basaltic lavas in the present state of our knowledge is a matter for inference only, but if we assume that they all belong to one period, they must be set down as Tertiary.

Some of the basic intrusive dykes, which are also widely distributed in the North-West, and form such pronounced features in the scenery, belong to a later period, that of the volcanic eruptions of Nullagine (Devonian) times ; for many cases have been noticed in which they traverse the Nullagine Beds for many miles. Since the Nullagine volcanic fires became extinct Western Australia appears to have known no outbreak of igneous activity until pretty well Tertiary times.

The history of volcanic action in Western Australia is thus the history of Pre-Cambrian, Devonian, and the Tertiary periods.

It is hardly possible within the scope of a single address to consider the whole question of the Geology of Western Australia. My object has been to point out what light has been thrown thereon through recent investigations, by merely touching the fringe of the subject, and my task has now been completed.

In the fulfilment of the task I have endeavoured to inflict to the full that punishment which, by the irony of fate, seems to be the recognised method by which a President conveys his appreciation of being made the recipient of one of the highest honours which his scientific brethren have within their power to bestow.

Whether or not I anticipate your endorsement of or disagreement with the verdict that the "Punishment fits the Crime," I *know* that I am voicing your feelings when I say that during our efforts to wrest from Mother Earth those secrets which are graven in mystic characters on her face, we geologists by merely wandering over the surface, exchanging the genial sunlight for the feeble flicker of the miner's candle, peering down the tube of the petrological microscope, calling to our aid the delicate chemical balance, or poring over the "Medals of Creation" in the seclusion of the Museum Cabinet, re-echo the sentiments of one of Germany's greatest poets and thinkers.

"Ach, wunderschön ist Gottes Erde!"
"Und schön auf ihr ein Mensch zu sein."

A. GIBB MAITLAND,

Government Geologist.

8.—Prevention of External Corrosion of Goldfields Water Supply Pipes.

(*a.*) PRELIMINARY REPORT.

Nature and Causes of Corrosion.—Before any suggestions could be made for the prevention of external corrosion of the Goldfields Water Supply pipes, it has been necessary to ascertain beyond doubt the causes of the corrosion, and as the result of experiments made, the following conclusions have been drawn :—The corrosion of steel in this case, as in most others, consists in the formation of a porous impure hydrated oxide of iron, rust, at the expense of the solid metal, owing to the interaction of the latter with water, and the oxygen dissolved by it out of the air, or otherwise derived. More particularly rust has been shown recently by Dr. Moody in a paper to the Chemical Society to consist mostly of the ferric hydrate, $Fe_2O_2\ (HO)_2$, with more or less small proportions of ferrous hydrate $Fe(HO)_2$ and ferrous carbonate $FeCO_3$ a result borne out by the experiments carried out by Dr. Earp and myself upon the rusting of the metal of the Goldfields Water Supply pipes, of which more anon.

It may be taken as an axiom that no chemical action can take place at ordinary temperatures between two permanent and dry solids, owing to the inertness of the molecules in the solid state, and to the impossibility of establishing sufficiently intimate connection between them. The presence of a third substance in the liquid or gaseous state, which is capable of dissolving even traces of either substances, sets up a condition of affairs very much more favourable to chemical action, since the dissolved molecules are in a far more active state than before, and intimate connection is assured per medium of the liquid or gas, whilst, most important of all, electrochemical action may also come into play.

One other fundamental fact must be noted. The most modern researches in chemistry have established the fact that in very many cases of chemical action the most important (chemical) factor is not the overwhelming proportion of the two main substances acting, but those apparently insignificant traces of other substances, which either profoundly alter the nature of the main materials, or else, in ways still obscure in many cases, more or less greatly enter themselves into the chemical actions going on and retard or accelerate them.

All these considerations bear directly upon the subject of this research, viz., the cause of the more or less rapid corrosion of the external surface of mild steel pipes laid underground. For, in the first place, we may assume without hesitation, that perfectly dry soil in contact with perfectly dry pipes, whether coated or not with any form of paint, would not cause the pipes to corrode. Steel will undoubtedly corrode to a very slight extent if suspended in air out of reach of rain or other visible moisture, since even the driest air contains water in solution, and thus three essentials to the formation of rust, viz., water, oxygen, and carbonic acid, are in contact with the steel. Such corrosion is undoubtedly extremely slow (except when, owing to the proximity of burning coal, sulphurous acid vapours exist in the air), and is reduced to an infinitesimal amount by coating the metal with any relatively inactive and impervious material, such as an asphaltic or graphite paint. The asphaltic paint (tar, asphalt, and maltha) used in coating the Water Supply pipes seems to have been, where not removed by rough handling, etc., very impervious and closely adherent, and therefore an excellent preservative. The corrosion from air is quite negligible therefore.

A much more active cause must be looked for, and failing air, this was sought for in the soils. A number of these have been examined, and more still being analysed with the greatest care, owing to the interesting results obtained up to the present. The soils consist for the most part of quartz sand, clay, and iron oxide in varying proportions. There is very good reason for believing that none of these main constituents exerts any chemical influence on the pipes. Vegetable matter is practically absent. Two causes of corrosion suggested themselves, viz. :—

1. The presence of pyrites in the soil undergoing oxidation in the presence of water and air with the production of sulphuric acid. Except possibly in one case, this was proved not to be the case since pyrites were absent, and on treatment of the soils with water the solution far from being acid was found to be alkaline, owing to the presence of carbonate of lime.
2. The presence of moisture in the soil, associated with an electrolyte (or substance capable of carrying an electric current) in the form of a salt of some strong mineral acid. In the light of the experiments made, there appears to be no doubt that this is the main, if not the sole cause of the corrosive effects observed.

Recent experiments in England have shown that :—

(*a*.) Chemically pure water is without effect upon iron or steel, such water being practically a non-conductor of electricity.

(*b*.) The addition of pure oxygen to chemically pure water does not make it more active towards iron.

(*c*.) The further addition of an electrolyte of the kind mentioned, such as common salt, gypsum, etc., sets up galvanic action, resulting in the formation of free acid and consequent active corrosion.

The electrolytic decomposition of an oxygen salt, such as a sulphate or carbonate, liberates at one pole (the anode) free oxygen together with the free acid corresponding to the salt, viz., either sulphuric or carbonic. The similar decomposition of a chloride yields chlorine in solution, an energetic solvent for iron. It is evident, therefore, that if any plate, or portion of a plate of iron or steel becomes the anode in the presence of a solution of such an electrolyte, energetic corrosion of that plate is to be expected.

The very modern science of metallography has shown that steel in common with most other commercial metals, is not a perfectly homogenous substance, but a mixture of two or more alloys. In the case of mild steel of the nature used in these pipes, the internal structure is found to be a main mass of "Ferrite," which is almost chemically pure iron, and embedded in this mass numerous small grains of "Cementite," a carbide of iron (Fe_3C), more or less regularly distributed. In these two constituents of the steel plates we have the necessary poles and connections to form, when in contact with a solution of an electrolyte, a series of small batteries, each causing corrosion.

Ferrite is a highly electro-positive substance, and therefore dissolves with comparative rapidity. Cementite is more electro-negative, and being also the cathode is but little affected by the action. That this electrolytic effect is not so small as one might at first expect is shown by the use to which it is put in determining the constituents of iron and steel by the etching of polished surfaces.

To obtain a rough quantitative idea of this action a series of experiments has now been made, using relatively pure water and solutions in water of the various electrolytes normally occurring in soils. A number of small bars, 3in. x ¾ x ¼ were cut from the metal of which the pipes in question are made, and roughly polished, these were then put in an upright position into well-stoppered bottles, and covered for half their depth with the following liquids :—

1. Distilled water, freshly boiled to remove all oxygen and carbonic acid.
2. Distilled water that had been standing some days and had probably absorbed considerable oxygen and carbonic acid from the air.
3. Distilled water saturated with carbonic acid.
4. Freshly boiled distilled water saturated with calcium carbonate (0.01 per cen. solution).
5. Do. with magnesium carbonate.
6. One per cent. solution of sodium bicarbonate.
7. Do. of calcium chloride.
8. Do. of magnesium chloride.
9. Do. of sodium chloride.
10. Saturated solution of calcium sulphate.
11. One per cent. solution of magnesium sulphate.
12. Do. of sodium sulphate.
13. Solution containing ½ per cent. each of magnesium chloride and sodium nitrate.

14. Do. sodium chloride and sodium nitrate.
15. One per cent. solution of sodium nitrate.
16. Water extracts of soil No. 1926.
17. Do. of No. 1962.
18. Do. of No. 1963.
19. Do. of No. 1924.
20. Do. of No. 1957.
21. Do. of No. 1956.

The results of these experiments were extremely interesting, in every case but one a noticeable amount of corrosion had taken place within the space of an hour, as shown by the formation of rust on the surface of the plates, and the appearance of a precipitate or deposit of iron oxide in the solutions surrounding them. The effects were watched for two days, when the steel bars were removed, and the iron removed from them was estimated.

These experiments show that :—

(1.) Rusting takes place in comparatively pure water containing a little oxygen and carbonic acid.

(2.) That the amount of rust formed is nearly double in the presence of a little common salt, sodium carbonate, or a mixture of magnesium chloride and sodium nitrate; whilst it is considerably increased in the presence of a little calcium carbonate, chloride or sulphate, magnesium sulphate, sodium sulphate, or nitrate. All these salts occur in the soils examined.

(3.) Water extracts of three soils where the pipes were said to be very bad yielded nearly double the amount of rust yielded by pure water.

This being so, the soils were examined with a view to determine the nature and quantity of the soluble salts contained in them. The following table gives the results in percentages of the soil :—

Laboratory No.	1835.	1813.	1814.	1815.	1816.
Locality, miles and chains	17·35	128·72	129·20	129·68	183·00
Condition of pipes	Bad	Bad	Fair	Very Good	Good
Calcium carbonate... ...	·014	·002	·038	·002	·025
Magnesium ,, ...	...	·019	...	·020	·038
Sodium ,, ...	...	·015	...	·014	·014
Calcium sulphate	·033	...	·002	...	...
Magnesium ,, ...	...	...	·040	...	...
Sodium ,, ...	...	·025	..	·013	·178
Sodium nitrate	...	Trace	·019	Trace	...
Calcium chloride	·037	...	...	...	...
Magnesium ,, ...	·037	...	·003	...	...
Sodium ,, ...	·076	·082	·200	·034	·355
Iron oxide and alumina ...	·010	·032	·015	·020	·014
Silica					·014
Total	·207	·176	·317	·103	·538
Nature of soil	Weathered diorite and grey clay	Coarse, grey, very sandy clay	Light brown, very sandy clay	Light brown, very sandy clay	Buff, very sandy clay

Laboratory No.	1861.	1862.	1863.	1864.	1868.
Locality, miles and chains	183·17	192·00	201·16	216·66	218·40
Condition of pipes	Good	Good	Fair	Bad	Fair
Calcium carbonate	·011	·014	·028	·025	·025
Magnesium ,, ...	...	·002	·004	·023	...
Sodium ,, ...	...	...	...	·006	...
Calcium sulphate	·024	...	...	...	·022
Magnesium ,, ...	·025	·032	·024	...	·056
Sodium ,, ...	·070	·061	·050	·085	·034
Sodium nitrate	...	...	...	...	...
Calcium chloride	...	...	...	..	...
Magnesium ,, ...	...	...	...	...	...
Sodium ,, ...	·266	·009	·018	·249	·162
Iron oxide and alumina ...	·028	·034	·012	·012	·011
Silica	·013	·006	·016	·038	·010
Total	·437	·158	·152	·438	·320
Nature of soil	Brown sandy clay	Yellow clayey sand	Light grey, sandy clay	Brown sandy clay	Light brown clay

Laboratory No.	1869.	1870.	1871.	1920.	1921.
Locality, miles and chains	241·01	267·70	306·70	313·40	315·40
Condition of pipes	Fair	Good	Fair	Fair	Bad
Calcium sulphate	·025	·009	·025	·026	·025
Magnesium ,, ...	·016	·009	·002	·009	·011
Sodium ,, ...	...	...	...	...	·019
Calcium sulphate	...	...	...	...	...
Magnesium ,, ...	·037	·001	·029	·013	...
Sodium ,, ...	·020	·024	·148	...	·020
Sodium nitrate	·012	...	...	...	...
Calcium chloride	...	...	...	...	...
Magnesium chloride ...	...	...	...	·005	...
Sodium ,, ...	·284	·084	·018	·030	·036
Iron oxide and alumina ...	·024	·007	·012	·004	·006
Silica	·006	·006	·022	·011	·036
Total	·424	·140	·256	·100	·132
Nature of soil	Light brown clay	Buff, very sandy clay	Dark brown clay	Brown sandy clay	Red sandy clay

Laboratory No.	1922.	1923.	1809.	1810.	1924
Locality, miles and chains	320·40	323·00	324·60	332·10	335·20
Condition of pipe	Bad	Bad	Bad	Good	Very bad
Calcium carbonate	·018	·021	·002	·025	·016
Magnesium carbonate ...	·014	·008	·024	·009	·005
Sodium ,, ...	·046	...	...	...	...
Calcium sulphate	...	...	...	...	...
Magnesium sulphate ...	...	·019	008	·034	·013
Sodium ,, ...	·015	·008	·005	·045	·027
Sodium nitrate	...	Trace	·006	·013	...
Calcium chloride	...	...	...	...	...
Magnesium chloride ...	...	...	...	...	...
Sodium ,, ...	·036	·302	·062	·203	·018
Iron oxide and alumina ...	·014	·006	·018	·032	·001
Silica	·016	·006			·011
Total	·159	·370	·125	·361	·091
Nature of soil	Red clay	Brown clay	Brownish grey sandy clay	Brown, very sandy clay	Brown sandy clay

Laboratory No.	1925.	1926.	1956.	1957.	1958.
Locality, miles and chains	336·18	336·38	340·50	353·77	354·21
Condition of pipe	Very bad	Very bad	Very bad	Fair	Fair
Calcium carbonate ...	·003	·022	·009	·019	·039
Magnesium carbonate ...	...	...	·005	·016	...
Sodium ,, ...	...	...	·011	·019	...
Calcium sulphate	·018	·098	...	...	·073
Magnesium sulphate ...	·031	·057	...	...	·050
Sodium ,, ...	...	·011	·034	·105	·108
Sodium nitrate	...	...	...	...	...
Calcium chloride	...	...	...	...	...
Magnesium chloride ...	·003	...	...	...	...
Sodium ,, ...	·032	·026	·036	·089	·053
Iron oxide and alumina ...	·004	·004	·016	·015	·003
Silica	·005	·007	·008	·011	·005
Total	·128	·225	·119	·274	·331
Nature of soil	Red sandy clay	Red sandy clay	Brown sandy clay	Red sandy clay	Red sandy clay

Laboratory No.	1959.	1960.	1961.	1962.	1963.
Locality, miles and chains	357·43	376·40	379·42	382·63	385·03
Condition of pipe	Bad	Bad	Bad	Good	Fair
Calcium carbonate ...	·022	·016	·017	·014	·023
Magnesium carbonate ...	...	·011	...	·012	·014
Sodium ,, ...	...	·026	...	·029	·008
Calcium sulphate	·274	...	·189	...	...
Magnesium sulphate ...	·120	...	·171	...	...
Sodium ,, ...	·278	·054	·482	·027	·037
Sodium nitrate	...	...	·004	...	..
Calcium chloride	...	...	...	...	...
Magnesium chloride ...	...	...	...	...	...
Sodium ,, ...	·102	·035	·506	·027	·146
Iron oxide and alumina ...	·002	·001	·003	·002	·008
Silica	·001	·005	·005	·013	·010
Total	·799	·150	1·377	·124	·246
Nature of soil	Red clay	Red clay	Red clay	Brown clay	Brown clay

This table shows that the whole of the soils examined contained soluble salts, varying in amount from one-tenth to one and a-third per cent. Corrosion more or less intense is therefore to be expected at all the points from which the samples were taken. This corrosion will be entirely prevented by the asphaltic covering where intact, but wherever it is chipped or scratched the pipe will be open to attack. This attack will be dependent upon—

(1.) The frequency with which the soil is wetted by rain or leakage.

(2.) The extent to which the soil retains moisture after rainfall owing to its topographical position or its physical structure. Clay pans and flats will be moist long after the ridges have dried and stiff clay will retain moisture for weeks after loose sand has lost all such through evaporation.

(3.) The quantity and nature of soluble salts in the soil. Within the limits shown by the analyses the effect will, as a rule, be greater where the total amount of salts is greater, but will be dependent still more upon whether or not those salts are derived from acids which have a strong affinity to iron. Chlorides, sulphates, and nitrates may be expected to have the worst effect.

Finally localisation of attack will result from localisation of exposed surfaces or of salts or moisture in the soil, and from lack of homogeneity of the steel.

Prevention of Corrosion.—Having thus arrived at a definite conclusion with regard to the causes of corrosion, it is a comparatively simple matter to suggest means of prevention, though the relative expense and adaptability of these means are matters for the consideration of the engineer in charge.

In short, what must be avoided is to allow moist soil to remain in contact with the bare metal of the pipes for any appreciable part of the year, especially where the ground is salty. This object is to be attained by—

(1.) Continually renewing the coating of the pipes, so as to preserve it practically intact.

(2.) Reducing leakage to a minimum.

(3.) Diverting all surface water from the pipe line.

(4.) Assisting the soil to dry up rapidly after rainfall.

This latter point is the only one which needs elucidation. The air of the interior is so dry at all seasons of the year and at times so hot, whilst the rainfall is so slight, that loose sandy soil will dry naturally too quickly to allow of extensive corrosion taking place. Stiff clay soils are however so retentive of moisture that where the soil is of this nature extra supervision of the pipes should be maintained with a view to keeping the coating intact, whilst the covering of soil should be reduced to a minimum, or even done away with, and any steps, locally applicable, taken to facilitate the draining and drying of the soil in the immediate vicinity of the pipes.

Renewals of the pipes will have to be undertaken as time goes on, and before such are made it would be well to have a thorough investigation made into the question of the suitability of mild steel for such work in the salty soils of the interior. Reasons, both practical and theoretical, point to its being far from an ideal material for such work.

In conclusion, I must acknowledge my indebtedness to Dr. F. S. Earp in the preparation of this report, that gentleman having made most of the necessary estimations and analyses.

EDWARD S. SIMPSON, B.E., F.C.S.,
Mineralogist and Assayer.

(*b.*) SECOND AND FINAL REPORT.

Since the presentation of my preliminary Report upon the corrosion of the G.W.S. pipes, the work of Dr. Earp and myself has been chiefly upon the completion of the analyses of soils from various parts of the pipe-line, upon determining the relative effect of these soils upon different brands of metal and upon experimenting with various substances likely to neutralise or retard the evil effect of the soils.

Analyses of Soils.—The accompanying Table 1 gives the analyses of 29 more soils from the pipe-track.

The variable action of these soils is dependent upon several independent factors, viz.:—

(*a.*) The state of the pipe coating.
(*b.*) The percentage of salts in the soil.
(*c.*) The capacity of the soil for retaining moisture.
(*d.*) The drainage of the soil.

The irregular pitting of the pipes has been imitated in the laboratory, and would also appear to be due to several causes, viz., irregular exposure of the pipe, lack of homogeneity of the metal, and water-line action.

TABLE 1.

Laboratory No.	**2087.**	**2088.**	**2089.**	**2090.**	**2091.**
Locality, miles and chains	2·52 from Weir.	4·61, Clackline.	4·62, Clackline.	4·72, Clackline.	6·36, Clackline.
Condition of Pipe	Bad.	Bad.	Very bad.	Bad.	Fair.
Calcium carbonate ...	·015	·003	·007	·005	·008
Magnesium ,, ...	...	·009	·002	·004	...
Sodium ,, ...	...	·055	...	...	...
Calcium sulphate	·005	...	...	...	·008
Magnesium sulphate ...	·018	...	·008	·004	·027
Sodium ,, ...	·023	·011	·033	...	...
Sodium nitrate	...	...	...	...	·001
Calcium chloride	...	...	...	...	...
Magnesium chloride ...	...	..	...	·007	·008
Sodium chloride	·015	·020	·100	...	·469
Iron Oxide and Alumina ...	·001	·006	·015	·006	·008
Silica	·018	·023	·003	·011	·015
Total	·096	·125	·068	·037	·544
Nature of soil	Dark grey sandy clay.	Greenish mica with clay & sand.	Dark grey sandy clay.	Dark brown clay and sand.	Grey sandy clay.

Laboratory No.	2095.	2127.	2128.	2129.	2130.
Locality, miles and chains	19·60 Werribee.	Bed, North side, Avon River.	Northam office yard.	Seabrook Rail Mile, 83·0.	Mendar, 92·60.
Condition of Pipe	Bad.	Good.	Bad.	Fair.	Good.
Calcium carbonate	·006	·005	·008	·009	·009
Magnesium carbonate	·005	·001	·014	·012	·013
Sodium ,,	...	...	·012	·067	·018
Calcium sulphate	...	...	...	...	.
Magnesium sulphate	·010	·013	...	...	...
Sodium sulphate	...	·003	·014	·010	·016
Sodium nitrate	...	...	minute trace.	minute trace.	minute trace.
Calcium chloride	...	...	...	...	...
Magnesium chloride	·001	...	...	...	...
Sodium ,,	·017	·016	·036	·032	·042
Iron Oxide and Alumina	·020	·005	·004	·009	·006
Silica	·075	·012	·016	·019	·014
Total	·134	·055	·104	·163	·118
Nature of soil	Brown grey sandy clay.	Light brown sandy clay.	Grey clay.	Light brown clay.	Grey sandy clay.

Laboratory No.	2131.	2151.	2152.	2153.	2154.
Locality, miles, and chains	Meckering, 100·60.	Wyola, 122·68.	Wyola, 122·71.	Wyola, 123·57.	Wyola, 124·40.
Condition of pipe	Fair.	Good.	Fair.	Fair.	Fair.
Calcium carbonate	·007	·017	·007	·007	·011
Magnesium carbonate	·012	...	·005	...	...
Sodium ,,	·010	...	...	...	...
Calcium sulphate	...	·008	...	·080	·009
Magnesium sulphate	...	·033	·006	·245	·008
Sodium ,,	·017	·034	...	...	...
Sodium nitrate	...	...	...	·001	minute trace
Calcium chloride	...	...	...	...	...
Magnesium chloride	...	...	·002	·055	·004
Sodium ,,	·038	·415	·029	3·050	·319
Iron oxide and alumina	·005	·012	·010	·156	·014
Silica	·021	·084	·160	·037	·044
Total	·110	·603	·219	3·631	·409
Nature of soil	Grey clay.	Grey sand, little clay.	Grey sand, little clay.	Grey sand.	Buff clayey sand.

Laboratory No.	2181.	2182.	2183.	2194.	2195.
Locality, miles, and chains	Wyola, 124·60.	Bungalla, 126·11.	Bungalla, 136·60.	Bungalla, 137·3.	Bungalla, 140·23.
Condition of pipe	Very bad.	Good.	Fair.	Very bad.	Very bad.
Calcium carbonate	·008	.004	·011	·006	·009
Magnesium carbonate	...	...	·014	·013	·013
Sodium ,,	...	...	·027	·012	...
Calcium sulphate	·001	·018	...	...	...
Magnesium sulphate	·019	...	..	...	·006
Sodium ,,	...	...	·020	·026	·015
Sodium nitrate	...	...	...	...	...
Calcium chloride	...	·006	...	...	...
Magnesium chloride	...	·012	...	.	...
Sodium ,,	·122	·001	·058	·087	·080
Iron, oxide, and alumina	·016	·006	·042	·028	·017
Silica	·099	·031	·266	·133	·156
Total	·265	·078	·438	·305	·296
Nature of soil	Grey clayey sand.	Pink sandy clay.	Grey sandy clay.	Grey clayey sand.	White sandy clay.

Laboratory No.	2196.	2197.	2240.	2241.	2242.
Locality, miles, and chains	Bungalla, 141·70.	Kellerberrin, 143·75.	Kellerberrin, 152·40.	Doodlekine, 154·40.	Doodlekine, 155·33.
Condition of pipe	Bad.	Good.	Bad.	Fair.	Bad.
Calcium carbonate... ...	·011	·011	·009	·028	·017
Magnesium carbonate ...	·012	·011	·009	...	·017
Sodium ,, ...	·027	·043	·061	...	·012
Calcium sulphate	...	...	...	...	...
Magnesium sulphate ...	...	...	...	·021	...
Sodium sulphate ...	·046	·012	·034	...	·028
Sodium nitrate	...	...	·028	·019	·007
Calcium chloride	...	...	...	...	...
Magnesium chloride ...	...	...	...	...	...
Sodium ,, ...	·222	·040	·053	·142	·102
Iron oxide and alumina ...	·002	·023	·031	·007	·015
Silica	·036	·118	·090	·021	·083
Total	·356	·258	·315	·238	·261
Nature of soil	Grey clayey sand.	Grey clayey sand.	Brownish grey sandy clay.	Buff sandy clay.	Grey clay.

Laboratory No.	2243.	2284.	2017.	2330.
Locality, miles, and chains ...	Hine's Hill, 167·58.	373·7 Soil in contact with incrustation.	326 Soil in contact with 2016.	361·70 Soil in contact with 2017.
Condition of pipe...	Very bad.	Bad ?	Bad ?	Bad ?
Calcium carbonate	·029	·016	·017	·024
Magnesium carbonate	·015	·016	...	...
Sodium ,, ...	...	...	...	...
Calcium sulphate	...	...	·033	·057
Magnesium sulphate	·017	·003	...	·070
Sodium ,, ...	·138	·092	...	·561
Sodium nitrate	·039	...	...	
Calcium chloride	...	...	·012	...
Magnesium chloride	...	...	·051	...
Sodium ,, ...	·356	·083	·126	·222
Iron oxide and alumina ...	·013	·009	·020	·014
Silica	·018	·008	·013	·018
Total...	·625	·227	·272	·966
Nature of soil	Buff sandy clay.	Bright red clay.	Buff clay.	Brownish red clay.

Composition of External Incrustation.—A typical sample of incrustation from the pipe in contact with soil No. 2284 of Table 1 was analysed with the following results :—

	per cent.
Iron peroxide, Fe_2O_3	36·96
Iron protoxide, FeO	6·44
Lime, CaO	1·08
Magnesia, MgO	·81
Water below 100°	4·05
Water above 100°	1·74
Carbonic anhydride, CO_2	3·68
Sulphuric anhydride, SO_3	·24
Chlorine, Cl	·43
Insoluble clay, etc.	43·80
	99·23

This is typical rust admixed with a good deal of soil. The presence of carbonates, sulphates, and chlorides shown by the analysis points to the influence of soluble salts in the formation of the incrustation.

Several other similar samples were examined and found to be identical with that analysed.

A qualitative analysis was also made of a sample of internal incrustation. This was of similar character, principally hydrated peroxide of iron with a little protoxide, carbonic acid, and mechanically held sand and organic matter.

Relative Corrosion of Iron and Steel.—Experiments have been made to determine the relative effect of the soils upon iron and steel, the idea being to determine, if possible, whether the steel at present in use was less suited for the purpose than iron or other steels. The metals tested were (1), Steel from present pipes ; (2), Mannesmann steel ; (3), soft iron. Bars of these metals were immersed in water extracts of the soils to such a depth that the area of metal exposed to the action of water was constant, viz., 27 sq. centimetres (4 3-16 sq. inches). Corrosion was apparent within a few hours after immersion, and after four days the amount of metallic iron removed from the bars in the form of rust was determined with the results in Table 2.

TABLE 2.

Extract from Soil No.	Pipe steel.	Mannesmann steel.	Iron.
	Milligrammes removed by corrosion.		
2182	11·3	19·8	9·4
2195	16·9	21·2	15·1
2196	23·5	24·9	21·6
2241	17·4	20·7	16·5
2243	15·0	24·5	Lost
Mixed extracts of 10 soils ...	10·5	10·5	10·2

As was expected from its more homogeneous structure, the action on iron was slightly less throughout than that on either steel. However the inferior strength and increased cost probably more than counterbalances the slightly greater resistance to corrosion. Of the two steels experimented on, that in the present pipes is decidedly more resistant.

In connection with the corrosion of steel water pipes by salts in the soil, the following extract is of interest. It is taken from a Bulletin of the United States Geological Survey on reinforced concrete pipes.*

Steel pipe is naturally limited to a thin shell on account of its great strength, weight, and cost. It is easily attacked by salts and acids, both on the inside by the water flowing through it and on the outside by the material surrounding it. A slight deterioration in so thin a shell means a large loss in strength, and the life of a steel pipe is therefore limited to a few years, depending upon the nature of the material in which it is laid. Experience has shown that in alkali ground in Southern California the life of a sheet-steel pipe is short. The life of the pipe may be lengthened by a coating, both inside and outside, of asphaltic material. The coating is applied by dipping the pipe into a hot bath of the asphalt mixture. If this dipping is not carefully done at just the proper temperature it is not likely to add much to the life of the pipe. The coating is liable to be broken in places by careless handling in transit from the factory to the work, and unless such places are recoated they are soon attacked, and the efficiency of the pipe is thus materially lessened. In all of the projects in the arid States more or less alkali ground is encountered, and in many of the projects provision has to be made for the drainage of the lands to get rid of the alkali. Under these circumstances other and more durable material than steel or iron must be sought.

---

* Experiments on steel concrete pipes on a working scale by John Washington, 1905.

Prevention of Corrosion.—Means were sought for preventing or at any rate checking the action of the salt of the soil on the pipe. Assuming, as stated in my previous report, that the cause of corrosion is the electrolysis of the dissolved salts with the consequent momentary liberation of substances of an acid character, reduction of corrosion should be brought about by the application to the soil, or to the surface of the pipe, of a substance which would either lower the conductivity of the salt solutions, or else immediately neutralise the liberated acid.

Substances of the former class appear mainly to be both expensive and difficult to apply practically. That they do materially reduce corrosion the following figures attest :—

—	Corrosion with solution before addition of alcohol.	Corrosion after addition of alcohol.
Pipe steel	19·1	8·9
Mannesmann steel ...	14·6	7·0
Iron	16·0	9·4

Substances of the latter class must be alkaline, but not carbonated alkalis, these give rise to carbonic acid under the influence of electrolysis. Limestone was therefore expected to be valueless, and found by experiment to be so. Effective substances would be such oxides, hydrates, and basic silicates, as are readily attacked by acids. The following substances were actually tried and found effective :—

(1.) Caustic soda.
(2.) Caustic potash.
(3.) Ammonia.
(4.) Quick lime.
(5.) Freshly slaked lime.
(6.) Sodium silicate (water glass).

Portland cement was not tried, but would undoubtedly be equally effective.

The effect of all these substances was to indefinitely prevent corrosion, provided fresh supplies of air were not allowed to reach the soil solution with which the metal was in contact. Herein lies the bar to their practical application. Air contains sufficient carbonic acid to convert lime, etc., in process of time into the corresponding carbonates, and then all their protective influence is lost. The experiments with lime were therefore interesting, but disappointing. Two steel bars were partly immersed in 1 per cent. solution of sodium chloride and sodium sulphate. In one hour signs of corrosion were apparent, and rapidly increased. After two days, the iron removed by corrosion was 26.3 and 22.3 milligrams respectively. The corrosion was general, but slightly more marked near the surface of the solution. The experiment was then repeated with solutions of the same salts containing in addition ⅛ per cent. of lime. For four days no action whatever was noticeable, after that a very slow corrosion set in at the water line only, where the solution had become saturated with atmospheric carbonic acid. The action was allowed to proceed for 70 days, with the following results :—

The corrosion was confined to the surface level of the liquid.

The steel was corroded to a maximum depth of 1½ millimetres at this point.

The rust formed nodular incrustations, portions of which dropped off from time to time.

The rates of corrosion were 2.5 and 2.9 milligrams per day, as against 13.1 and 11.1 when no lime was used.

A similar experiment was made with the water extract of soil No. 2284, with the following results :—

—	Corrosion after six days.	
	Without lime.	With lime.
Pipe steel	35·7	6·1
Mannesmann steel ...	38·1	10·3
Iron	44·2	3·3

The deductions to be drawn are that a thin layer of lime between the pipes and the soil would considerably retard corrosion at first, but that by absorption of carbonic acid from the air the protective effect would be gradually lessened until it became nil at the end of a very few years at most.

What may be called chemical methods of checking corrosion do not therefore appear to be practically successful. One is obliged to fall back on the purely mechanical one of keeping the pipes sheltered from action by a strongly and closely adherent and impervious coating of some material having itself no effect upon the steel.

I have been unable to obtain details of the Barff process of treating pipes. It consists, I believe, of heating them in an atmosphere of steam until a thick and very adherent coating of magnetic oxide forms on the surface. This coating is said to be an excellent protection against rusting.

Time and experience have led to an almost universal belief in the tar-asphalt coating. It was lately stated in a technical journal that unless the carbolic acid be previously removed from the coal tar, such a coating has itself an action on the pipe, and tends to increase the loosening and flaking off which is the main objection to this coating. This is a point which should be noted if local tar is used. Mr. Reynoldson's own suggestion to use a jute binding with the tar-asphalt coat appears to be an excellent one. To avoid destruction in the hot asphaltic mixture the jute may require a previous soaking in a heavy oil, such as crude vaseline. Experiments on a working scale with this jute covering would be well justified, and at the same time as an alternative the toughening effect of the addition to the asphalt mixture of 10 or 15 per cent. of flake mica.

Graphite paint is largely used in the United States for the protection of metal work above ground with what are said to be excellent results. This, too, should be worth a working trial.

Final Conclusions.—The results of all the experiments made by myself, as well as the accounts of others made elsewhere, confirm me in the following opinions :—

1. Steel corrodes slowly when kept quite dry.

2. Steel rusts comparatively rapidly in contact with air and water.

3. The life of steel pipes is very considerably shortened when the soil in which they are laid contains over 0.1 per cent. of soluble salts, such as common salt, gypsum (calcium sulphate), etc.

4. They can only be preserved by a perfectly adherent and impermeable coating which itself has no action on the metal.

5. Such a perfect coating, owing to necessary rough handling, being impossible of attainment, the nearest possible approach to it should be secured.

6. In view of the necessary imperfections of the coating, the strongest efforts should be made to keep the soil in contact with pipes absolutely dry by drainage, diversion of surface water, checking leaks, substituting sand for clay as a covering, etc.

7. Iron is somewhat more resistant to corrosion than steel, and occasionally it may be more economical to use it in place of steel for pipes. In each case the relations between costs and efficiency must be carefully worked out.

EDWARD S. SIMPSON, B.E., F.C.S.,
Mineralogist and Assayer.

Note.—Researches into the causes of the corrosion of the pipes on the Goldfields Water Supply main were made in the Survey Laboratory during the year 1906. To assist in these investigations it was found necessary to enlist the services of Dr. F. S. Earp for a period of six months ; his salary, however, was paid by the Goldfields Water Supply Administration, in whose interest the special work was carried out. The information obtained as a result of the laboratory investigations of the soils from the Goldfields Water Supply pipe track, and their effect upon pipe steel and iron, are of considerable interest, and of more than mere local importance.

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WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 27.

II

Palæontological Contributions to the Geology of Western Australia.

BY

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Curator of the Australian Museum, Sydney, N.S.W.;

F. CHAPMAN,
Palæontologist to the National Museum, Melbourne, Vic.; and

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Issued under the authority of the Hon. H. Gregory, M.L.A., Minister for Mines.

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PREFATORY NOTE.

The five palæontological contributions to which the Geological Survey is indebted to the authors, Messrs. Etheridge, Chapman, and Howchin, have been received since the publication of the last Bulletin, No. 10, in 1903. Two of the present contributions throw light upon the geological age of the Collie River Coal measures and are of some scientific interest in their relation to the important question of the distribution of the Glossopteris flora; two add considerably to our knowledge of the organic remains of the Carboniferous rocks as developed in the State, whilst the last, containing descriptions of the Foraminifera from the Upper Tertiaries as developed in the neighbourhood of Gingin, is an addition to our knowledge of a group of organisms to which but little attention has as yet been paid.

A. GIBB MAITLAND,
Government Geologist.

Geological Survey Office,
Perth, 26th March, 1907.

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I.—*Plant Remains from the Collie Coalfield.*

BY

R. ETHERIDGE, junr.

Curator of the Australian Museum, Sydney, N.S.W.

Before venturing an opinion on the identity of the plant remains from this locality, it may be well to review the previously held opinions as to the age of the coalfield.

In 1891 Mr. H. P. Woodward remarked as follows:—"The age of these beds it is impossible to determine at present, as no fossils have yet been found, but to judge from its chemical composition (*i.e.,* the coal) it is probably an old Mesozoic coal, as it is more like a lignite than a bituminous coal." (*a.*)

Subsequent to this specimens were evidently submitted to Mr. R. Etheridge, F.R.S., who detected the presence of plant remains, and reported in these words—"Portions of *Glossopteris* or *Nœggerathia* occur in this coal. This is interesting, as both these genera are abundantly represented and very characteristic of the coal of Newcastle, New South Wales; so that we are probably dealing with a coal from the same horizon (geologically) and marked by the same flora" (*b.*).

In 1894, Mr. H. P. Woodward, on three occasions, referred to this subject. In two official reports he says:—"This coal, although bearing such a close resemblance in its composition to the Mesozoic coals, is a true coal of Carboniferous age, as has been proved by fossil plant remains" (*c.*), and in the second instance he quoted the above remarks of Mr. Etheridge (*d.*). In a paper "Notes on the Geology of Western Australia," he remarked:—"A small patch of the Upper Carboniferous formation has been discovered upon the Collie River, consisting of shales, sandstones, fire-clays, with coal seams" (*e.*)

In 1897 Mr. E. F. Pittman, in a short communication to the Royal Society of New South Wales, remarked: "In character it (*i.e.,* the coal) very much resembles the Clarence River coal of New

---

(*a*) Annual General Report of the Government Geologist for the year 1890 (1891), p. 40.

(*b*) West Australian "Year Book" for 1891, by M. A. C. Fraser, 1892, p. 128.

(*c*) *Ad Interim* Report of the Department of Mines (W.A.) for the half-year ending 30th June, 1894, p. 11. (*d*) Report on the Collie Coalfield, etc., W.A. Parl. Papers, 1894, No. 9, p. 3. (*e*) Geol. Mag., 1894, 1 (4), p. 548.

South Wales . . . Fossil plant remains are very scarce, but portions of two were obtained, and Mr. R. Etheridge, jun., after some hesitation, pronounced them to belong to the genus *Sagenopteris,* thus confirming the impressions that the measures are Mesozoic" (*a*). This is all I have been able to gather relating to the different views held as to the age of the Collie Coalfield.

In the present collection, four localities are represented—Moira Colliery, Collie Burn Bore, Cardiff Mine, upon the Collie Coalfield, and near Bullsbrook, seventeen miles north of Midland Junction—all yielding plant remains.

1. *Moira Colliery.*—The coal at this locality contains portions of narrow ribbon-like leaves with a single median rib, remains of woody-tissue, "mother of coal," woody-tissue retained in the form of compressed stems, and leaves of *Glossopteris.*

2. *Collie Burn Bore.*—One face of a section of the bore core exhibits a leaf of *Glossopteris.*

3. *Collie Cardiff Mine.*—On the surface of a piece of black Carbonaceous shale is a fragment of a leaf, probably *Glossopteris.*

4. *Near Bullsbrook* (Bullsbrook beds).—Black Carbonaceous shale with *Vertebraria.*

None of the *Glossopteris* leaves from Moira Colliery are in a good state of preservation, but although the surfaces are highly carbonised the net venation is distinctly visible here and there. The leaves are broadly lanceolate in outline, after the type of *G. browniana,* Brong., but the venation is much finer, and I do not think they can be referred to this species ; indeed, the veins appear to be finer than most of the leaves we are accustomed to see associated with the Coal Measures in Eastern Australia. I cannot distinguish any tendency of the leaves to form digitate fronds, as in *Sagenopteris,* and this fact, joined with the presence of firm, broad, and distinct mid-ribs, or costæ, compels me to regard the leaves as those of *Glossopteris,* rather than those of any other genus. The presence of that peculiar semi-jointed organism known as *Vertebraria* at the fourth locality is interesting. The plant remains known under this name are constantly associated in our Eastern Coal Measures with the leaves of *Glossopteris,* and are now regarded by Palæobotanists as the roots or rootlets of *Glossopteris.*

These facts constrain me to support the age assigned to the Collie Coalfield by my father, viz., Permo-Carboniferous.

I have re-examined the specimen mentioned by Mr. Pittman, but in the light of the leaves from Moira Colliery, I must abandon my previous determination, and look upon it also as a leaf of *Glossopteris.*

(*a*) Journ. R. Soc. N. S. Wales, 1897 (1898), xxxi., p. xlviii.

II.—Notes on Fossils from the Collie Coalfield, Western Australia, in the collection of the National Museum, Melbourne,

BY

FREDERICK CHAPMAN, A.L.S., F.R.M.S.,

Palæontologist, National Museum, Melbourne, Victoria.

Introductory Remarks.

The question of the age of the coal-bearing strata in the South-West District of Western Australia was conclusively settled by Sir Frederick McCoy in 1898.

A series of plant-remains from the Collie Coalfield had previously been sent to the National Museum by Sir John Forrest, then Premier of Western Australia, and in a telegram to the Premier, Professor McCoy reported, respecting the fossils and coal specimens forwarded to the Museum, as follows :—

> I am now able to state that the deposit is of the exact geological age of the great coalfields of Newcastle, New South Wales. The specimens of coal from the Collie bore cores are quite equal to the best coals of that district. *Glossopteris browniana* is the commonest and most easily recognised of the fossil plants you sent me. I heartily congratulate you on this magnificent discovery, and so valuable an addition to the natural wealth of your Colony. (*a*)

No scientific account of the collection of fossils sent to McCoy has yet been published. This, together with the fact that previous writers on the subject were undecided as to the age of the coal beds, whether mesozoic or palæozoic, leads me to record the following observations. Besides the plant remains, a small but interesting series of Foraminifera was discovered in the sandstones interbedded with the coal.

Previous Literature.

The first references as to the age of these coal deposits are to be found in the Mining Handbook to Western Australia (*b*), and in the Report on the Department of Mines, W.A., (*c*) both by the Government Geologist, Mr. H. P. Woodward, who stated, in the

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(*a*) The *Morning Herald*, Tuesday, 18th October, 1898, p. 5. (I am indebted to Mr. T. S. Hall, M.A., for directing my attention to the above published telegram).

(*b*) Woodward, H. P.—"Mining Handbook to the Colony of Western Australia," 1894, pp. 86 and 32.

(*c*) *Ad Interim* Report on the Department of Mines for the half-year ending 30th June, 1894, Appendix I. Report on the Collie Coalfield, pp. 9-11 (with plan).

first-mentioned work, that Mr. R. Etheridge senr., reported the discovery of *Glossopteris* or *Nœgaerathia* in the Collie coal seams, and concluded that the coal is of palæozoic age. This statement regarding the age of the coal was said to have been afterwards withdrawn by Mr. Etheridge senr. I have not been able to find any published note by Mr. Etheridge of the rescinded determination, (*a*) but in either case the credit of originally assigning these beds correctly to the palæozoic series remains with him.

From the spoil heap about the mine, Mr. E. F. Pittman (*b*) obtained two fragments of leaves, which he submitted to Mr. R. Etheridge, junr., who suggested they might possibly belong to the mesozoic genus *Sagenopteris.* Mr. Pittman concluded, partly from the foregoing evidence, that the coal-bearing strata are of mesozoic age.

In view, therefore, of the uncertainty respecting the age of these beds, owing to the scarcity of fossils, it is singularly fortunate that the present valuable series of plant remains was secured by the Premier, Sir John Forrest. The announcement as to the age of the coal field by McCoy was not made, however, until after the reading of Mr. Pittman's paper before the Australasian Association for the Advancement of Science, and its publication in the Geological Survey Records of New South Wales.

General Descriptions of the Specimens.

The collection of plant remains from the Collie Coalfield (*c*) consists of *Glossopteris* leaves and stem fragments which occur on pieces of carbonaceous shale, and on the surfaces of a whitish sandstone with thin, black carbonaceous partings. The sandstone specimens and some of the shales are from cores obtained by boring.

The Shales.

Some of the plant-bearing shales are earthy in texture, and show a fair sprinkling of mica folia on the split surfaces. The majority of the slabs bearing the finest leaves consist of a close textured, bituminous shale, which shows a bright surface where abraded.

(*a*) *See* Pittman, E. F.—Notes on the Geology and Mineral Deposits of Portions of Western Australia.—Records, Geological Survey, N.S.W., vol. 6, pt. 1, 1898, p. 6.

(*b*) Pittman—*loc. supra cit.*, p. 5.

(*c*) Received at the National Museum from the Premier's office, Perth, 7th October, 1898. In the letter accompanying these specimens, Sir J. Forrest writes :—"These fossils are average specimens of the fossils met with in an area of from five to six miles from East to West, and occur between the coal seams, which are of varied thickness, from 2ft. 6in. to 12ft. The fossils on this field, I am informed, are similar above and below the coal seams."

A microscope section of this bituminous shale proves it to consist of fine, amorphous, hydro-carbonaceous particles, and only in one case was anything like a spore detected. This had the appearance of a sub-elliptical cell, with a clear circular area situated near to one side of the interior, and bore some resemblance to one of the cells of *Pila,* an organism whose remains constitute the bulk of the European bogheads.

The Sandstone.

There are two specimens of sandstone, both being cores from a boring. One of these is a greyish rock with numerous papery carbonaceous layers averaging about 5mm. in thickness, the intervening sandstone layers being about 2mm. thick. This specimen is somewhat micaceous, both white and brown micas being present, the former preponderating. On one surface of the core a flattened stem-like fossil occurs, apparently of the nature of a plant stem or a rhizome. The rock shows distinct cross-bedding, pointing to the shallow water conditions prevailing when the deposit was laid down.

The second sandstone specimen shows only one carbonaceous seam, although the core is 35mm. thick. The stratification lines have a slight dip, and there are indications of current bedding. This specimen reveals some interesting structural features when submitted to a microscopic examination. The granules of which the rock consists are largely made up of quartz, some felspar, and numerous garnets, with occasionally mica. The rock is loosely compacted, the interstices being occupied by a white, powdery material, probably of the nature of kaolin. Of the mineral constituents of the rock garnet is the most abundant ; it is usually in fractured grains, but sometimes crystal faces are visible, and the colour varies from dark ruby to almost colourless. Quartz occurs next in abundance, usually in rounded, but not polished, grains ; and sometimes shows included strings of cavities and acicular rutiles. The felspar is more generally orthoclase, often showing zoning ; occasionally there are fragments of microcline, with perthite structure. This material was probably derived from the garnetiferous granites or gneisses which are found in this locality.

Amongst the finest powder of this rock, after crushing and washing, there occurred a few examples of Foraminifera of unusually minute dimensions, and probably dwarfed on account of their brackish water habitat.

On treating the powder of this sandstone with hydrochloric acid a slight effervescence was noticed, due, no doubt, to the presence of a few remnants of foraminiferal tests.

Descriptions of the Fossils.

PLANTÆ.

GLOSSOPTERIS BROWNIANA, *Brongniart.*

(Plate I., fig. 1.)

Glossopteris browniana, var. *australasica,* Brongniart, 1830, Hist. Végét. Foss., vol. I., p. 223, pl. LXII., fig. 1 *G. browniana,* Arber, 1903, Cat. Gloss. Flora, Brit. Mus., p. 48, pl. II., figs. 1-5 ; pl. III., figs. 1, 2 ; Text fig. 16.

This is the species originally determined by McCoy from specimens in the present collection, where there are at least three examples. The secondary veins of our specimens are more closely arranged than in typical examples of *G. browniana,* otherwise there is no difficulty in assigning them to the above form. The figured example is a portion of a large leaf having a strong midrib (a feature considered by Zeiller to be characteristic of the variety *indica*) bearing several distinct, subcircular depressions, such as were at one time thought to indicate fructification. On account of the irregular disposition of these depressions, however, one might also suggest a comparison with an ascomycetous fungoid growth of the nature of *Hysterium* (*a*), although there is no visible raised border to the pits, suggestive of a peritheca.

GLOSSOPTERIS INDICA, *Brongniart.*

(Plate I., fig. 2 ; pl. II., fig. 2.)

Glossopteris browniana, var. *indica,* Brongniart, 1830, Hist. Végét. Foss., vol. I., p. 223, pl. LXII., fig. 2.

G. indica, Schimper, Arber, 1905, Cat. Gloss. Flora, Brit. Mus., p. 64, Text figures 17, 18A.

There are several well-preserved examples of leaves referable to the above species in the present series. One of these very closely resembles Zeiller's figure of a leaf from South Rewah, India (*b*), both in outline and in its close and fine venation.

Some of the leaves also show particularly fine nervation near the midrib, a character held by some authors as distinctive of the variety *communis,* (*c*) as here shown in pl. II., fig. 2.

Certain of the latter type of leaf from the Collie Coalfields possess a thick midrib, and narrow anastomosing veins emerging from the midrib at a rather acute angle. Zeiller (*d*) and Arber (*e*)

(*a*) *cf. Hysterites* on leaves of *Cordaites.* White, D.—Mon. U.S. Geol. Surv., vol. xxxvii., 1899, p. 14, pl. iii.

(*b*) Palæontologia Indica, new series, vol. ii., No. 1, 1902, p. 8, pl. iii., fig. 3.

(*c*) *G. communis,* Feistmantel, 1881, Palæontologia Indica, vol. iii., Pt. 1, p. 16, pl. xvii. figs. 1, 2, 2A ; Pt. 2, p. 98, pl. xxiv.A, etc. *Idem,* 1890, Mem. Geol. Surv., N.S. Wales Palæontology, No. 3, p. 123, pl. xvii., figs. 2, 6.

(*d*) Palæontologia Indica, new series, vol. ii., No. 1, 1902, p. 81. (*e*) Cat. Gloss. Flora, 1905, p. 67.

regard *G. communis* as synonymous with *G. indica,* and it certainly is difficult to separate some of the leaves figured under both names by Feistmantel. Leaves agreeing in other respects with the variety *communis* usually show a tendency to become petiolate.

The specimen figured on Pl. II. (fig 2) shows a rounded depression near the margin, which is perhaps merely a hole torn in the leaf. Similar depressions and holes have been frequently observed and figured as probable examples of fructification. (*a.*)

GLOSSOPTERIS ANGUSTIFOLIA, *Brongniart.*

(Plate II., fig. 1.)

Glossopteris augustifolia, Brongniart, 1830. Hist. Végét. Foss., vol. 1, p. 224, pl. LXIII., fig.1.

G. browniana, var. *angustifolia,* Brongniart, Seward, 1904. 2nd Report, Geol. Surv. Natal and Zululand, p. 99, pl. IV. figs. 3, 4.

G. angustifolia, Brongniart, Arber 1905 ; Cat. Gloss. Flora., Brit. Mus., p. 72. Text figs. 18 B and 19.

One example, referable to this species, occurs in the present series. It is part of a narrow leaf, curved, and with nearly parallel sides. The median rib appears to have been fairly thick, and the spaces between the secondary veins narrow. This type of leaf, like the preceding, is well represented in the Gondwanas of India, and in the coal measures and associated rocks in New South Wales and South Africa.

(?) GLOSSOPTERIS GANGAMOPTEROIDES, *Feistmantel.*

(Plate II., figs. 3, 4.)

Glossopteris gangamopteroides, Feistmantel, 1890, Mem. Geol. Surv. N.S. Wales, Pal. No. 3, p. 125, pl. XX., fig. 4.

This species was originally described from the Newcastle coal beds, New South Wales.

A good example of the upper portion of a leaf, with its intaglio, corresponding to the above form, and another, somewhat doubtful, example, occur in the present series. The figured example shows the fine sulcate midrib and closely approximating secondary veins.

In the absence, especially towards the apex, of a strongly defined midrib, the distinguishing character of the genus *Glossopteris,* the above form might almost be equally assigned to *Gangamopteris,* especially since leaves of the latter generic type sometimes show a distinct median sulcus. (*b*) Arber places this species in the synonymy of *G. browniana* (op. cit., p. 50).

(*a*) *See* Brongniart, Bunbury, and Feistmantel; also Seward in Science Progress, vol. vi., 1897, p. 178; and Arber, Quart. Journ. Geol. Soc., vol. lxi., 1905, p. 333. (*b*) *See* Chapman, Vict. Naturalist, vol. xxiii., 1906; p. 5, pl.

An interesting feature in our specimen (Pl. II., figs. 3, 4), is the occurrence of what appears to be fructification on the lateral areas of the leaf close to the midrib. It consists of several ovoid, almost reniform pustular or capsular bodies whose point of attachment seems invariably to be situated between the secondary veins. In the enlarged drawing (fig. 4) the upper sac-like body is inflated, whilst the lower is apparently empty. Zeiller has figured similar but much larger bodies on leaves of *Glossopteris angustifolia.* (*a*) The oval-shaped bodies symmetrically arranged on *Glossopteris* leaves from the Greta coal measures, N. S. Wales, as described by Professor David, (*b*) may also be compared with the present occurrence.

In a paper on sporangium-like organs of *Glossopteris,* lately published by E. A. Newell Arber, (*c*) the evidence adduced for the existence of Sporangia on the ordinary large *Glossopteris* fronds is regarded by that author as, at present, unsatisfactory. It is therefore the more interesting to find what now appears to be additional evidence of the existence of fructification in *Glossopteris,* as shown in the present example.

In may be noted *en passant* that the actual length of the bodies seen in the specimen before us compares almost exactly with the Sporangium-like bodies described by Arber from the New South Wales specimens in the British Museum and at Cambridge. The shape of the small bodies on our specimen differs however somewhat materially, in being more regularly ovoid or reniform, as opposed to the foliar shape of Arber's examples.

RHIZOMA OF GLOSSOPTERIS [VERTEBRARIA].

(Plate I., fig. 3.)

One of the fossils in the present collection is referable to the rhizome of *Glossopteris,* which, before the work of Zeiller, (*d*) Oldham, (*e*) and Arber, (*f*) was separately distinguished as *Vertebraria indica,* Royle, (*g*) which possibly includes McCoy's species *V. australis.* (*h*) It is worthy of note that Mr. Newell Arber (*loc cit.*) has pointed out, in the course of his examination of the Clarke collection of fossil plants in the Woodwardian Museum, Cambridge, that "to McCoy is due the credit of first recognising the nature of *Vertebraria,* and the heterophyllous character of *Glossopteris,* neither of which were admitted until a few years ago. (*i*)

Our specimen is somewhat slender, and has a characteristic transverse furrow. The fragment measures 43mm. in length, and

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(*a*) Bull Soc. Géol., France ser. 3, vol. xxiv., 1896, p. 370, pl. xviii., figs. 3, 3^{b}. (*b*) Proc. Linn. Soc., N. S. Wales, ser. 2, vol. v., 1891, pp. 424-425. (*c*) Quart. Journ. Geol. Soc., vol. lxi., 1905, p. 334. (*d*) Bull. Soc. Géol., France, vol. xxiv., 1896. (*e*) Records, Geol. Surv., India, vol. xxx., 1897. (*f*) Quart. Journ. Geol. Soc., vol. lviii., 1902, p. 8. (*g*) Illustr. Bot. and Nat. Hist. Himal. Mountains, 1839, p. xxix., pl. ii., figs. 1-3. (*h*) Ann. Mag., Nat. Hist., vol. xx., 1847, pp. 145-147, pl. ix , fig. 1. (*i*) *See* McCoy, *tom. supra cit.*, p. 151.

has an approximate diameter of 8mm. It occurs on a cleaved surface of shale from a bore core, and was cut off abruptly by the bore tube.

(?)RHIZOME OF A FERN, PROBABLY ALLIED TO RHIZOMOPTERIS.

(Plate I., fig. 4).

This specimen bears some comparison with *Rhizomopteris etheridgei* of Seward, (*a*) a fossil occurring in Mesozoic coal beds of Coal Creek Mine, Korumburra.

Our example lies on the surface of a carbonaceous parting in sandstone. On close examination it is seen to differ from the mesozoic fossil in having numerous small pilule-shaped bodies on parts of its surface, in the place of the scars or circular pits seen in other portions of the surface. The scars are generally grouped in a rudely parallel manner, are deep and rounded at one end, and shallow at the other, where they trail off into a fine linear groove. Our specimen does not show the large circular scars of *Rhizomopteris etheridgei*, figured on the same plate (*loc. cit.*).

Zeiller's figured specimen of *Dictyopteridium sporiferum*, Feistmantel, (*b*) from the Lower Gondawanas of India, also shows a certain resemblance to our fossil. As Zeiller remarks regarding the Indian specimen, ours may possibly be the rhizoma of a fern, or as Seward suggests in the case of the Jurassic specimens, a fern stem, if not a rhizome.

A STEM-LIKE FRAGMENT OF DOUBTFUL AFFINITY.

(Plate II., fig. 5.)

This fragment is of a woody nature, judging from the thick carbonaceous layer remaining. It occurs on the surface of a sandstone bore-core, having thin carbonaceous partings. The fossil is vertically grooved in a somewhat interrupted manner, and carries deep lanceolate scars or pittings at intervals. This latter feature reminds one of the knorria stage of a slender lepidodendroid stem, but that the scars are uniformly depressed and excavated. The transverse flexuosity seen in this fragment would make it appear related to a structure like that of *Vertebraria*.

FORAMINIFERA.

By breaking down some of the whitish sandstone accompanying the coal-seams, and carefully washing out the finer residues from the sand, a few tests of Foraminifera were discovered. The Foraminifera are exceptionally minute, and are evidently depauperated varieties of the species they represent. It was therefore difficult to recognise their distinctive characters in most cases. There are also

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(*a*) Rec. Geol. Vict., vol. i., Pt. 3, 1904, p. 175, pl. xvii., figs. 30-34 (*cf.* fig. 33).
(*b*) Palæontologia Indica, new series, vol. ii., No. 1, 1902, p. 24, pl. iv., fig. 8.

present in the washings numerous fragments of a calcareous nature, which are perhaps referable to the same group of organisms, but too obscure to allow of anything to be said regarding them.

The starved condition of the foraminiferal tests is in perfect keeping with the brackish or estuarine condition of the area in which these normally marine animals lived at the time.

The presence of marine organisms in the strata associated with the Collie coal beds points undoubtedly to the view that these deposits are of allochthonous origin, that is to say, due to drifted material, subject to the influence of marine or estuarine conditions.

FAM. LITUOLIDÆ.

GENUS ENDOTHYRA, *Phillips*.

(?) ENDOTHYRA, SP. (Pl. II., fig. 8 *a, b*).

This specimen is probably related to *Endothyra*, rather than *Truncatulina*, on account of its apparently irregular and granular shell-structure. Otherwise it might be compared with *T. variabilis*, d'Orbigny (*a*), which shows the same plan of growth and shell-contour.

Length, .143mm. ; width, .1mm.

FAM. TEXTULARIIDÆ.

GENUS VALVULINA, *d'Orbigny*.

VALVULINA PLICATA, *Brady*, Pl. II., figs. 10 *a-c*.

Valvulina plicata, Brady, 1876, Carboniferous and Permian Foraminifera, Pal. Soc. Mon., vol. XXX., p. 88, pl. IV., figs. 10, 11.

Our specimen resembles *Discorbina globularis*, d'Orb. sp., in outline, but the shell-structure is finely arenaceous, and the test is more regularly built. It is closely comparable with Brady's figured specimen.

V. plicata has been recorded by Dr. Brady from the Lower and Upper Carboniferous limestones of England and Scotland, and from the Fusulina beds of Iowa, U.S.A. It has not been found in Permian strata.

Greatest width .107mm.

GENUS BULIMINA, *d'Orbigny*.

(?) BULIMINA, SP., Plate II., figs. 9 *a, b*.

The reason for assigning this example to *Bulimina*, but with some reserve, is on account of the comma-shaped and laterally situated oral aperture. Tricarinate *Buliminae* are almost unknown. Comparison may be made with *B. trigona*, Chapman, from the Taplow Chalk, (*b*) which, although trigonulate, is not sharply

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(*a*) Ann. Sci. Nat., vol. vii., 1826, p. 279, No. 8.

(*b*) Quart. Journ. Geol. Soc., vol. xlviii., 1892, p. 515, pl. xv., f. 8.

carinate on the edges, nor does it have concave lateral surfaces, like the above example. In the latter feature our shell resembles a *Rhabdogonium,* but there the comparison ends. There is a faint indication of a textularioid septation, but the shell is too small and obscure to clearly make out the arrangement of the chambers.

The genus *Bulimina* is already represented in Carbo-permian strata, having lately been recorded by Mr. Howchin and the writer from Wollong, New South Wales. (*a*)

Length, .117mm. ; greatest width, .08mm.

FAM. ROTALIIDÆ.

GENUS TRUNCATULINA, *d' Orbigny.*

TRUNCATULINA HAIDINGERI, *d'Orbigny, sp.*

(Pl. II., figs. 7 *a, b.*)

Rotalina haidingeri, d'Orbigny, 1846, Foram. Foss. Vienne, p. 154, pl. VII., figs. 7-9.

Truncatulina haidingeri, d'Orbigny, sp., Chapman and Howchin, 1905, Mon. Permo-Carb. Foram, Mem. Geol. Surv. N.S.W., No. 14, p. 18, pl. III., figs. 3 *a, c.*

From the texture of the test, our specimen is undoubtedly hyaline, and is nearest related to the somewhat variable and ubiquitous species, *T. haidingeri.* It has been described quite recently from the marine series of the Carbo-permian of New South Wales, where the specimen found attained its usual dimensions, owing doubtless to the purer marine conditions there prevailing, as compared with those experienced by the foraminifera of the Collie coal-field area.

A form of *Truncatulina* nearly related to the above is the *T. bouena,* d'Orb. sp., which was recorded from the Calcaire de Namur (Carboniferous limestone) of Belgium. (*b*) It differs from *T. haidingeri,* however, in having a depressed form of test, and more numerous chambers.

Greatest width, 18mm.

GENUS PULVINULINA.

PULVINULINA *cf.* EXIGUA, *Brady.*

Pulvinulina exigua, Brady, 1884, Rep. Chall. vol IX., p. 696, pl. CIII., figs. 13, 14.

Our example is a neat form, with few visible chambers and a lobulated periphery. It seems to be most nearly related to the above species, but in the absence of other specimens for comparison it is impossible to be certain of its identity with the recent species.

Greatest width, .18mm.

(*a*) Mem. Geol. Surv., N.S.W. Pal. No. 14, Mon. Foram. Permo-Carb. Limestones of N.S.W., 1905, p. 14, pl. ii., f. 7.

(*b*) Mon. Pal. Soc., vol. xxx., 1876, p. 139, pl. vi., f. 11.

Note on the Foraminifera.

Perhaps the most significant and interesting occurrence in this small series of Foraminifera is that of *Valvulina plicata.* As will have been seen already, it is essentially a Carboniferous form, and although extremely dwarfed, is, in other respects, quite typical. Two of the remaining species point in a general way to the Palæozoic aspect of the deposit, and the two rotaline genera *Truncatulina* and *Pulvinulina* are already well established as amongst the oldest forms of the hyaline group.

III.—Fossils from Mingenew, Irwin River Coalfield, Western Australia, collected by Mr. E. S. Simpson, Mineralogist and Assayer.

BY

R. ETHERIDGE, Junr.,

Curator of the Australian Museum, Sydney, N.S.W.

A small collection of casts and impressions, collected by Mr. E. S. Simpson, Mineralogist and Assayer on the staff of the Geological Survey, at Mingenew, Irwin River Coalfield, was forwarded to me for identification by Mr. A. Gibb Maitland, Government Geologist.

The casts are converted into limonite, often concretionary, and the former frequently ill-preserved, in consequence specific determination has proved tedious and by no means satisfactory.

Amongst the more important forms are *Productus undatus, Defrance, Spirifera avicula,* G. B. Sby. (pl. III., f. 1 and 2) and numerous impressions of *Fenestella* or *Protoretepora,* common in our eastern Permo-Carboniferous beds and a large *Aviculopecten* (pl. IV., f. 1). I have selected a few of the more important forms for detailed notice.

On the whole the aspect of these fossils is decidedly that of the Permo-Carboniferous of New South Wales.

GENUS DIELASMA, *King,* 1850.

(Mon. Permian Foss. England, 1850, p. 146.)

DIELASMA NOBILIS, *sp. nov.*

(Plate IV., figs. 2-4 ; Pl. VI., figs. 1, 2.)

Sp. Chars.—Cast oval-deltoid, biconvex, large, attenuated dorsally, enlarged medio-ventrally ; ventral margins deeply folded or insinuated. Pedicle valve the most convex, arched longitudinally ; trilobate, a prominent, rounded, median fold from the umbo forwards, traversed by a groove, and two similar but ill-defined marginal folds without grooves, separated from the median by broad, shallow sulci ; umbo large, but not overhanging, with a large foramen oblique to the longitudinal axis of the shell ; fissures left by the dental plates delicate and moderately long. Brachial valve less convex than the pedicle, with a broad median sulcus and two lateral, entire, rounded folds. Sculpture concentric, fine.

Obs.—This fine and remarkable form is comparable in size to *Dielasma cymbæformis*, Morris (*a*) but differs in the bi and trilobate nature of the brachial and pedicle valves respectively, and the curvature outline of the lateral and ventral margins of the united valves. It is, however, with *D. inversa*, De Kon. (*b*) that the, at first sight, extraordinary likeness exists, but there are the following dissimilar points :—Whilst in *D. inversa* the fold of the brachial valve is traversed by a deep sulcus, flanked by supplementary lateral folds, in *D. nobilis* the centre of the same valve is in itself the sulcus bounded by a lateral fold on each side, but devoid of flanking folds ; the pedical valves of both forms on the other hand agree.

I figured a very large *Dielasma* from the Bowen River Coalfield beds in Queensland (*c*) equal in size to the present shell, but possessing the characters of *D cymbæformis*, Morris, to a much greater degree than those of the present form.

GENUS SPIRIFERA, *J. Sowerby*, 1816.

(Mineral Conchol., Gt. Brit., 1816, II., p. 41)

SPIRIFERA, *sp. ind.*

(Plate III., figs. 3-5 ; Pl. VI., fig. 6.)

Sp. Chars.—Casts oblong-triangular ; valves unequally convex; cardinal margins as wide as the casts, and the alar angles rounded ; ventral margins deeply insinuated centrally, and dorsally curved laterally. Convexity of the pedicle valve greatly in excess of that of the brachial, in other words it is very much the deeper of the two ; sinus well defined, extending far forwards ; umbo elevated and apparently not incurved ; cardinal slopes wide, concave, or in some examples almost flat ; area narrow, as wide as the valve cast ; delthyrium ill-defined (in the casts) ; deep and wide fissures left by the removal of the dental plates, extending to about one-third towards the ventral margin ; pedicle cavity and muscular area rather deltoid or ob-pyriform ; adductor scar linear ; the deductor scars wider and lanceolate, longitudinally striate ; no trace of a septum. Brachial valve deeply insinuated medio-ventrally, with a high rounded fold, bearing a well-marked impression of the septum extending for at least half the length of the fold ; dental sockets deep and large. Sculpture consisting of 7-8 rounded costae in the pedicle valve, and 6-7 similar ribs in the brachial valve ; fold and sinus devoid of costae.

Obs.—Casts of this *Spirifera* are very common in the Mingenew beds, but I cannot refer it to any of those occurring in our eastern

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(*a*) Morris-Strzelecki's Phys. Descrip. N. S. Wales, etc., 184. p. 278, 117, f. 4, 5.

(*b*) De Koninck-*Rhynchonella*, Foss. Pal. Nouv.-Galles du Sud, Pt. 3, 1877, t. 11, f. 11, 11 *a* and *b* ; Etheridge—Rec. Geol. Surv. N. S. Wales, 1898, v., Pt. 4, p. 175, t. 19,;f. 1-13.

(*c*) Geol. Pal. Queensland, etc., 1892, t. 9, f. 10, 11.

deposits. It is remarkable in the possession of very wide and open cardinal slopes giving considerable depth to the pedicle valve. In form, so far as mere casts will permit of an opinion, it is a modification of the *S. grandicostata* type, but with less extended alar prolongations. The only ally I know of is *S. Stutchburyi*, mihi, (*a*) although it is distinct. The casts have been carefully compared with all those met with in the Permo-Carboniferous of New South Wales and Queensland, but in the absence of the testaceous covering, I refrain from applying a name, as the presence of this investment greatly alters the appearance of the shell.

GENUS CYRTINA, *Davidson,* 1858.

(Mon. Brit. Carb. Brachiopoda, No. 2, 1858, p. 67.)

CYRTINA CARBONARIA, McCoy, var. AUSTRALASICA, *Eth. fil.*

Cyrtina carbonaria, var. *australasica,* Eth. fil., Proc. Linn. Soc. N. S. Wales, 1889, VI. (2), p. 210, t. 17, f. 7-8.

Obs.—A poor ill-preserved cast of the exterior, mutilated about the hinge line, *may* represent this species, but the determination can hardly be regarded as more than a suggestion. It is a pedicle valve. much arched longitudinally and traversed by the remains of coarse costae.

GENUS CLEIOTHYRIS, *King,* 1850.

(Mon. Perm. Foss. England, 1850, p. 137.)

CLEIOTHYRIS MACLEAYANA, *Eth. fil.* ?

Cleiothyris macleayana, Eth. fil., Bull. Geol. Survey W. Austr., No. 10, 1903, p. 16, t. 3, f. 10-20 (for synonomy).

Obs.—A single decorticated exterior cast of a pedicle valve, *may* also indicate the presence of this remarkable species in the same beds. It possesses the outline of this fossil and traces of the characteristic spinose laminae, but as the umbo is wanting, I do not lay too much confidence on the determination.

GENUS PRODUCTUS, *J. Sowerby,* 1814.

(Mineral Conchol., 1814, I., p. 153.)

PRODUCTUS SUBQUADRATUS, *Morris.*

(Plate III., figs. 6 and 7.)

Productus subquadratus (Morris), Eth. fil., Geol. Pal. Q'land, 1892, p. 252, t. 38, f. 7-10, t. 40, f. 5.

Obs.—A mutilated specimen of a large *Productus* is, I believe, referrable to the Queensland form I identified with Morris's species. There is little interest attached to the specimen other than the record except that, as in the above, there is clear evidence of an area on the brachial valve. The question of an area in *Productus* has already been discussed by the late Dr. T. Davidson, Messrs. James

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(*a*) Etheridge—Geol. Pal. Queensland, 1892, p. 231, t. 38, f. 4-6.

Hall and J. M. Clarke, myself, and others, and although by no means a common feature, there can be no doubt that both an area and fissure exist in some *Producti*.

GENUS CHONETES, *Fischer*, 1837.

(Oryctographie Gouv. Moscou, 1837, p. 134.)

CHONETES, *sp. ind.*

(Plate IV., fig. 5.)

Obs.—There are numerous casts of the united valves of a small Chonetine shell, with the valves always more or less open although united along the cardinal margin. The presentation of these remains is peculiar :—Of the pedicle valve it is always an external impression that is seen ; attached is the brachial valve exhibiting strong imbricating laminae of growth. The position of this valve would lead to the belief that the interior was in view ; it may have been so originally, but now the whole of the test has been dissolved away, or removed, leaving the growth laminae exposed.

Similar concentric laminae are to be seen on the exterior of the brachial valves of the characteristic W. Australian *Chonetes Pratti*, Dav. (*a*.) These casts are not, in my opinion, this species, for the impressions of the exterior of the pedicle valve are devoid of a sulcus, and uniformly convex throughout, and this convexity is very pronounced for a *Chonetes*. I figure one of these casts as they seem to indicate the presence of another species of *Chonetes* distinct from *C. Pratti*.

GENUS DELTOPECTEN, *Eth. fil.*, 1892.

(Geol. Pal. Q'land, 1892, p. 269.)

DELTOPECTEN SUBQUINQUELINEATUS, *McCoy*.

(Plate V., figs. 1-3.)

Aviculopecten subquinquelineatus, McCoy, Ann. Mag. Nat. Hist., 1847, XX. p. 298, t. 17, f. 1.

Sp. Chars.—Casts truncato-orbicular, biconvex, practically equivalve and equilateral. Cardinal margins of somewhat less width than that of the entire shell ; ventral, antero- and postero-ventral margins rounded, semi-circular or perhaps sub-semi-circular. Ears large, nearly equal, flat, separated from the body of the casts by well-defined abrupt slopes, particularly the anterior slopes ; anterior ears large, triangular, the outer margins convex, terminating below in a slight byssal insinuation ; posterior ears pointed, the outer margins insinuated more or less deeply. Hinge line narrow, with several continuous resilium furrows, and a large widely deltoid semi-concentrically striated resilifer ; umbos equal, pointed. Sculpture consisting of numerous (McCoy says twenty-five) primary costae, proceeding direct from the umbos, whilst interpolated between

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(*a*) Bullen Newton—Geol. Mag., 1892, ix. (3), t. 14, f. 9 and 12.

every two of these is a secondary costa, which does not reach an umbo ; at the margins of the casts are supplementary finer tertiary costae, one between each primary and secondary ; interspaces flat ; concentric laminae of growth wide apart and often well marked.

Obs.—This is another common form at Mingenew. I am unable to separate it from McCoy's species except by the most trivial characters derived from the sculpture, the variability in number of the tertiary costae.

In 1892 I pointed out that an Australian *Aviculopecten,* then referred by me to *A. illawarensis,* Morris, possessed not only the resilium furrows of *Aviculopecten,* but also the "central cartilage pit" of *Pecten,* and proposed for this combination of characters the name *Deltopecten.* The present casts from Western Australia possess both in a marked degree, and it will be interesting to ascertain whether or no McCoy's type is similarly provided. If it does not, the casts now referred to his species will require to be reconsidered, notwithstanding their otherwise close resemblance.

GENUS MODIOLA, *Lamarck,* 1799.

(Prodrome-Mem. Soc. Hist. Nat. Paris, 1799, p. 87.)

MODIOLA ? *sp. ind.*

(Plate V., fig. 5 ; Pl. VI., fig. 5.)

Sp. Chars.—Casts strongly mytiliform, valves moderately convex increasing in width posteriorly; cardinal margins arched; ventral margins insinuated forming feeble sigmoidal curves. Anterior ends small and obtuse ; posterior ends much expanded, gradually flattening to the margins, which are rounded, with neither alations nor insinuations. Umbos apparently subterminal, with evenly rounded diagonal slopes, the surfaces above gradually sloping away to the cardinal and posterior margins, but below abrupt and declivitous to the ventral margins. Hinge characters unknown, but apparently quite edentulous. Muscular scars not observed. Sculpture of feeble laminae of growth, with very fine regular interstriations.

Obs.—In the absence of hinge details, it is very difficult to determine the generic position of these casts. In outline they are very like some Mesozoic *Mytili.* I have already described two mytiloid shells from the Australian Permo-Carboniferous—*Modiomorpha* (?) *mytiliformis* (*a*) from the Middle or Marine Series of the Bowen River Coalfield in Queensland ; and *Modiola* (?) *hartleyensis* (*b*) from the Upper Marine Series of Hartley in this State. So far as the specimens at my disposal permit me to judge, they appear to constitute an intermediate form between the two shells already mentioned. Although possessing well-marked diagonal slopes, abrupt on the antero-ventral sides as in *M.* (?) *mytiliformis,*

(*a*) Etheridge—Geol. Pal. Queensland, 1892, p. 273.

(*b*) Etheridge—Rec. Geol. Survey N. S. Wales 1902, Vol. VII., pt. 2, p 68, t. 18, f. 10 and 11.

these casts at the same time represent what must have been a very much more elongate and symmetrical shell. They appear to more closely approach *M.* (?) *hartleyensis* and notwithstanding there is no trace of the prominent outstanding growth lamellae of the latter, the West Australian specimens may prove to be that species.

GENUS MYALINA, *De Koninck,* 1844.

(Descrip. Anim. Foss. Terr. Carb. Belgique, 1844, p. 125.)

MYALINA (?) MINGENEWENSIS, *sp. nov.*

(Plate V., fig. 4 ; Pl. VI., figs. 3 and 4.)

Sp. Chars.—Casts large, obliquely triangular, gibbous, alate posteriorly, slightly produced anteriorly ; cardinal margins straight, nearly as wide as the casts ; ventral ends produced and narrowed, margins rounded ; anterior ends possibly produced, the margins oblique, straight (?), without indication of insinuation ; posterior ends flattened, forming alations, probably with entire rounded margins. Umbos apparently subterminal, large ; diagonal slopes prominent, high and rounded, on their posterior sides graduating into the alations, but on the antero-ventral abrupt and rather steep, leaving between them and the margins of the casts more or less flattened spaces. Cardinal margin not exhibiting any trace of teeth, but anterior to the umbos traversed by resilium furrows. Muscular impressions unknown. Sculpture fluctuating-radiate, extending over the whole surface.

Obs.—I am unable to satisfactorily identify these casts with any already described Australian Carboniferous or Permo-Carboniferous species. The only possible suggestion I can make is that they may be allied to Dana's [*Cypricardia*] *acutifrons*, (*a*) but this suggestion must only be accepted as a possibility. The absence of well preserved anterior ends amongst these casts and the questionable insinuation of the dorso-posterior margins render a satisfactory identification out of the question.

There are seven specimens, all casts of the interior except one, which is a partial impression of the exterior displaying radio-fluctuating costae, which cover not only what would be the body of the valve, but also extend on to the alation, where they are parallel to the cardinal margin. I cannot detect any muscular impressions. No trace of cardinal teeth is visible, but on one example there are the remains of resilium furrows anterior to the umbo. It is, however, a legitimate conclusion to suppose that similar furrows existed on the posterior side also.

To what genus these casts belong, it need hardly be pointed out, is equally uncertain. For the want of a better I have tentatively referred them to *Myalina*, De Koninck, but were it not for the ab-

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(*a*) Dana—Wilkes U.S. Explor. Exped., 1849, x. (Geol.), t. 8, f. 4, *a* and *b*.

sence of cardinal teeth, *Limoptera,* J. Hall might put in an equally good claim to their reception.

Whether the subject of plate VI., fig. 4, is a plastically flattened example of the same form, I am unable to say, but the great difference in the amount of convexity causes me to doubt it. In such a case this cast will represent a distinct species.

IV.—*Descriptions of Carboniferous Fossils from the Irwin River, collected by Mr. C. F. V. Jackson, late Assistant Government Geologist.*

BY

R. ETHERIDGE, Junr.,

Curator of the Australian Museum, Sydney, N.S.W.

I.—Introduction.

The fossils described in the following pages were collected by Mr. C. F. V. Jackson, when Assistant Government Geologist, and forwarded to me for identification by Mr. A. Gibb Maitland, Government Geologist. They were obtained, with the exception of one specimen, from a highly calcareous shale, some pieces of which are almost limestone, below the coal seams at the Irwin River.

The facies of these organic remains is eminently that of the Carboniferous as distinguished from the higher Permo-Carboniferous. Only four species are, with certainty, identical with forms found in the latter formation in Eastern Australia, viz.:—a Foraminifer (*Nubecularia*), *Productus subquadratus, Fenestella fossula,* and *Aviculopecten Sprenti;* a second bivalve (*Stutchburia*) may be so, but the specimens are not in a sufficiently good state of preservation to warrant the expression of a more emphatic opinion. One very interesting fossil is present—a Goniatite, referable to the genus *Gastrioceras.*

II.—Description of the Fossils.

FORAMINIFERA.

GENUS NUBECULARIA, *Defrance,* 1825.

(Dict. Sci. Nat., 1825, XXXV., p. 210.)

NUBECULARIA STEPHENSI, *Howchin.*

(Plate X., figs. 4-9.)

Nubecularia lucifuga, var. *Stephensi,* Howchin, Proc. Austr. Assoc. Adv. Sci. for 1893 (1894), p. 345, t. 10, f. *a*, t. 11, f. *a*.

Nubecularia Stephensi, Chapman and Howchin, Mem. Geol. Survey N.S. Wales, Pal. No. 14, 1905, p. 5, t. 1, f. 1 and 2, t. 3, f. 13 and 14, t. 4, f. 1 and 4.

Obs.—On the internal casts of several shells, on the inner and exterior surfaces of testiferous specimens, and scattered through the pieces of calcareous shale are numerous examples of this interesting Foraminifer, originally described by the Rev. W. Howchin from the Carboniferous beds of the Piper River, Tasmania, in all three stages, the spirilline, rectilinear, and acervalline. Several specimens exhibit a granular exterior, when the white test is perfectly preserved ; one of the free uncoiled or rectilinear tubes is 3mm. long, and I figure a very beautiful example, in section, of the spirilline condition passing into the rectilinear. The partition walls, or "septa" are also distinctly visible in many of the natural sections, and are, as Mr. Howchin has expressed it, "remarkably uniform."

Nubecularia has already been recorded by Prof. T. W. E. David from the Irwin River beds. (*a*)

ACTINOZOA.

GENUS PLEUROPHYLLUM, *Hinde,* 1890.

(Geol. Mag., 1890, VII. (3), p. 195.)

PLEUROPHYLLUM AUSTRALE, *Hinde.*

Plate VII., fig. 1 ; Pl. VIII., fig. 10).

Pleurophyllum australe, Hinde, Geol. Mag., 1890, VII. (3), p. 196, t. 8*a* f. 1a-f.

Pleurophyllum australe, Eth. fil., Bull. Geol. Survey W. Austr., No. 10, 1903, p. 8.

Obs.—A natural fractural section of this coral is worth referring to as it differs to some extent from either of those figured by Dr. Hinde, as in his Fig. 1*d* the small cardinal septum is flanked by a prominent bulbous-ended septum on either side. Here the counter septum is shortened and very bulbous at its apex, with the four smaller ordinary septa between it and the alar septa on each side, united to it ; in all there are twenty-six septa as described by Hinde. This section in the economy of the coral is, in all probability, intermediate between Hinde's figs. 1*e* and 1*f*.

POLYZOA.

GENUS FENESTELLA, *Lonsdale,* 1839.

(Murchison Silurian System, 1839, p. 677.)

FENESTELLA FOSSULA, *Lonsdale.*

(Plate VIII., figs. 11-13).

Fenestella fossula, Lonsdale, Strzelecki's Phys. Descrip. N. S. Wales, etc., 1845, p. 269, t. 9, f. 1, 1*a*.

Obs.—There are portions of two examples, which, from their appearance probably represent infundibuliform polyzoaria. The reverse, or non-zoecious faces are presented to view in both instances, but in one a portion of the polyzoarium has been re-

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(*a*) David—Mem. Geol. Survey N. S. Wales, Pal. No. 14, 1905, p. xiv.

moved, revealing the impressions of the zoeica. The fenestrules are long-oval in outline, very regularly measuring one millimetre in longitudinal diameter. The interstices and dissepiments are also very regular in growth, the former measuring one-third of a millimetre in transverse diameter ; the reverse of the interstices is delicately costate, the costæ decorated with microscopic granules. On the obverse, or zoecious face, the interstices are angular, each with a median keel ; the zoecia average three on each side a fenestrule.

Our experience of this "lace-coral," gained through an examination of New South Wales material, leads to the belief that it is open to much variation in the size of the mesh, and the relative strength of the dissepiments and interstices ; too great restriction, therefore, cannot be placed on its specific limits ; were this to be done, endless specific names could be coined.

BRACHIOPODA.

Genus Dielasma, *King,* 1850.

(Mon. Permian Foss. England, 1850, p. 146.)

Dielasma, *sp.*

(Plate VIII., figs. 7-9.)

Obs.—Three fragmentary specimens, with a highly punctate test-structure represent this genus. They appear to be of the type of the European *D. sacculus,* var. *hastata,* J. de C. Sby., rather than that of the Australian var. *amygdala,* Dana.

Genus Seminula, *McCoy,* 1844.

(Synop. Carb. Lime. Foss. Ireland, 1844, p. 158.)

Seminula subtilita, *Hall ?*

(Plate VIII., figs. 3-6.)

Seminula subtilita (Hall), Hall and Clarke, Introd. Study Brach. (13th Ann. Report State Geol. N. York for 1903 (1894), II., Pal., t. 35, f. 17).

Seminula, sp., Eth. fil., Bull. Beol. Survey W. Austr., No. 10, 1903, p. 17, t. 1, f. 5, t. 3, f. 21.

Obs.—Several examples of a *Seminula,* some slightly crushed, others not quite perfect, appear to be identical with that already figured from Baracooda Pool, Arthur River. They are either the above species or *S. ambigua* J. Sby., of the European Carboniferous Limestones, but possibly more allied to the former. Some varieties of *S. ambigua* are with difficulty distinguished from specimens of *S. subtilita ;* indeed, the two supposed species may be identical. The whole of the eight specimens have a fibrous and impunctate test.

GENUS SPIRIFERA, *J. Sowerby*, 1816.

(Mineral Conchol. Gt. Brit., 1816, 11, p. 41.)

SPIRIFERA, *sp.*

(Plate X., fig 1.)

Obs.—A large transversely ovate-triangular shell is represented by its pedicle valve, highly exfoliated, and with the fold broken away. The front, or ventral margin was deeply insinuated, and the alar angles, although not long, were sharply pointed. The costæ, approximately nine on each side, were strong, simple, probably angular, and but little radiating. It does not belong to the *S. convoluta* group as represented in our Permo-Carboniferous rocks by *S. avicula*, G. Sby., and *S. vespertilio*, G. Sby., proper. On the other hand this shell does fall within a series represented by a *Spirifera*, figured by Morris as *S. vespertilio*, (*a*) but which was, I believe, erroneously referred by the latter to G. Sowerby's species. In the present chaotic state of our Permo-Carboniferous Spirifers, it is difficult to say what this particular figure of Morris's does represent, but it certainly is not a long-winged form like *S. avicula*.

GENUS RETICULARIA, *McCoy*, 1844.

(Synop. Carb. Lime. Foss. Ireland, 1844, p. 142.)

RETICULARIA LINEATA, *Martin.*

Spirifera lineata (Martin), Davidson, Mon. Brit. Carb. Brach., Pt. 5, 1858, p. 62, t. 13, f. 1-13.

Reticularia lineata, Foord, Geol. Mag., 1890, VII. (3), p. 153.

Reticularia lineata, Eth. fil., Bull. Geol. Survey W. Austr., No. 10, 1903, p. 16.

Obs.—This species has already been recorded from the Irwin River by Mr. A. H. Foord. There are several examples in the present collection in various stages of preservation.

GENUS PRODUCTUS, *J. Sowerby*, 1814.

(Mineral Conchol. Gt. Brit., 1814, I., p. 153.)

PRODUCTUS SEMIRETICULATUS, *Martin, sp.*

Productus semireticulatus, (Martin), Davidson, Mon. Brit. Carb. Brach., Pt. 5, No. 4, 1861, p. 149, t. 43, f. 1-11, t. 44, f. 1-4.

Productus semireticulatus, Eth. fil., Bull. Geol. Survey W. Austr., No. 10, 1903, p. 18, t. 2, f. 3-5.

Obs.—Some crushed shells with the highly reticulate surface so characteristic of the dorsal half of this species are assumed to

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(*a*) Morris-Strzelecki's Phys. Descrip. N. S. Wales, etc., 1845, t. 17, f. 3.

be evidence of its occurrence in this deposit, although a similar test sculpture is to be found in other *Producti,* e.g., *P. spiralis,* Waagen, etc.

PRODUCTUS TENUISTRIATUS, var. *Foordi,* Eth. fil.

(Plate IX., figs. 4-6.)

Productus tenuistriatus, De Verneuil (?), var *Foordi,* Eth. fil., Bull. Geol. Survey W. Austr., No. 10, 1903, p. 19, t. 1, f. 3 and 4, t. 3, f 22.

Obs.—A single, rather exfoliated, example of this interesting fossil, with the valves in apposition presents all the characters mentioned either in Mr. Foord's description, or that by myself. The pedicle valve is well arched longitudinally, the apex of the umbo overhanging the dorsal margin ; the brachial valve is deeply concave. It is an elegant and well-proportioned species of the *P. lineatus,* Waagen, group, but with affinities to *P. cora,* D'Orb.

PRODUCTUS UNDATUS, *Defrance.*

Productus undatus (Defrance), Davidson, Mon. Brit. Carb. Brach., Pt. 5, No. 4, 1861, p. 161, t. 34, f. 7-13.

Productus undatus, Foord, Geol. Mag., 1890, VII. (3), p. 152, t. 7, f. 6.

Obs.—Numerous examples of this well-known Carboniferous *Productus,* already recorded from the Irwin River by Mr. A. H. Foord, are present in the matrix blocks in various states of preservation, both pedicle and brachial valves. These do not appear to resemble the more typical forms of *P. undatus* with the regular rolling concentric undulations so much as they do a special figure of Davidson's (*a.*) representing a specimen from the Carboniferous rocks of Derbyshire, in which the undulations are irregular and ill-defined. It may be mentioned that *Productus undatus* is an important member of the Gympie fauna in Queensland.

PRODUCTUS SUBQUADRATUS, *Morris* (?).

(Plate VII., figs. 2-4 ; Pl. VIII., fig. 1.)

Productus subquadratus (Morris), Eth. fil., Geol. Pal. Q'land, etc., 1892, p. 252, t. 38, f. 7-10, t. 40, f. 5.

Obs.—There are several examples of a *Productus* in various stages of exfoliation possessing all the characters of form and proportions of this remarkable species, but I have not succeeded in isolating the cardinal margin or internal structure. The specimens present the following features :—

The pedicle valve is quadrate-triangular, gibbous, inflated and longitudinally geniculate, the sides straight and wall-like, but in-

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(*a.*) Davidson—Mon. Brit. Carb. Brach., Pt. 5, No. 4, 1861, t. 34, f. 7.

clined to expand around the margins; there is also a pronounced sinus extending from the umbonal region to the front, rendering the valve more or less bilobate; the cardinal margin is less than the width of the shell. The brachial valve is flat internally, the margins bevelled outwards, the width of the bevel increasing ventrally. Although all the specimens are exfoliated to a greater or less extent, closely set spine-bases of the *P. pustulosus* type cover the surfaces of both valves, with long linear spine-channels extending from them on the deeper test layers.

The Irwin River specimens do not attain to the same size as those from the Mount Britton Goldfield, Queensland, but the former are certainly believed to be identical with the latter. *P. subquadratus* was not figured by Morris, and further it must not be overlooked that great uncertainty exists regarding the correct specific names which should be used in referring to Australian Permo-Carboniferous *Producti,* not only in the case of the present fossils, but even in connection with *P. brachythærus*, G. Sowerby, and *P. brachythærus,* Morris. We know that under this name Morris certainly included two species, (*a*) and we have now some reason to surmise that even the figure (*b*) to which the name was restricted does not represent G. Sowerby's idea of his species. The subject is under investigation, and later on will be treated in Monograph form by Mr. W. S. Dun and myself.

Genus Chonetes, *Fischer,* 1837.

(Oryctographie Gouv. Moscou, 1837, p. 134.)

Chonetes Pratti, *Davidson.*

(Plate VIII., fig. 2 ; Pl. IX., fig. 7 ; Pl. X., fig. 2.)

Chonetes Pratti, Davidson, Geologist, 1859, p. 116, t. 4, f. 9-12.

Chonetes Pratti, Bullen Newton, Geol. Mag., 1892, IX. (3), p. 542, t. 14.

Chonetes Pratti, Eth. fil., Bull. Geol. Survey W. Austr., No. 10, 1903, p. 23.

Obs.—Three specimens are present, one in a fair state of preservation, and two imperfect. The first is a brachial valve, with the cardinal margin of the pedicle valve exposed above it armed with its spines ; the long narrow area is also visible. The others are less perfect pedicle valves, but on one, in which the external testaceous layer is not preserved, the "orifices on the ribs," and the "minute perforations" in the intercostal spaces, described by Mr. Newton are distinctly visible. On the second of these specimens the very fine concentric lines described by Mr. Newton are visible. The orifices on the ribs appear to me to be the bases of costal spines.

(*a*) Etheridge—Proc. R. Phys. Soc. Edinb., 1880, v., p. 285. (*b*) Morris-Strzelecki's Phys. Descrip. N. S. Wales, etc., 1845, t. 14, f. 4c.

PELECYPODA.

Genus Aviculopecten, *McCoy,* 1851.

(Ann. Mag. Nat. Hist., 1851, VII., p. 171.)

Aviculopecten Sprenti, *Johnston.*

(Plate VII., fig. 5 and 6.)

Aviculopecten Sprenti, Johnston, Proc. R. Soc. Tas. for 1886 (1887), p. 9.

Aviculopecten Sprenti, Johnston, Syst. Acc. Geol. Tas., 1888, t. 14, f. 11.

Obs.—We have in the Permo-Carboniferous of N. S. Wales a very elegant group of Palæopectens that, after seeing Mr. Johnston's type of his *A. Sprenti,* kindly lent to us by Mr. A. Morton (*a*), Curator of the Tasmanian Museum, Mr. W. S. Dun and myself cannot separate from that species. It is an exceedingly ornate form and appears to pass through a wide range of variation, both as to size and number of costae. Johnston's figure in no way does justice to the specimen, the finer details of sculpture being omitted. *A. Sprenti* will be fully described in a Monograph (*b*) now in preparation by Mr. W. S. Dun and myself on the N. S. Wales Permo-Carboniferous Palæopectens.

From the Irwin River are four more or less imperfect specimens corresponding, so far as their state of preservation will permit me to judge, with our N. S. Wales forms. They display the characteristic outward sweep of the costae, which are divisible into 12-13 primary, with between each pair a secondary rib, and again on each side of the latter a tertiary riblet, but the last may be at times irregularly developed, or here and there absent ; it is in this feature that variation takes place. The auricles are, unfortunately, ill-preserved, but such characters as are discernible agree with those of the auricles of *A. Sprenti.* The specimens are all what I term "decorticated," *i.e.,* with the test layers more or less removed, although not strictly in the condition of internal casts. In consequence of this the concentric lining and decorating spines are not preserved, but, at the same time, the positions of these spines on the primary costae are indicated, here and there, by slight enlargements of, or nodules on the latter. The auricles are separated from the body of the valve in each case by declivities, and semi-sulci, but there is no byssal sinus.

It is a debatable point whether or no the name *A. Sprenti* should be retained for these shells in preference to Salter's much earlier *A. hiemalis,* a name given to a shell from the Carboniferous rocks of Niti in the Himalayas. Mr. Carl Diener's figures of the latter (*c*) are, to all intents and purposes, indistinguishable from some of our N. S. Wales examples of *A. Sprenti.* If, as Mr. Diener

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(*a*) Since this was written news of Mr. Morton's death has been received.

(*b*) Now published.

(*c*) Diener -Himalayan Foss. (Pal. Ind.) i., Pt. 4, 1897, t. 5, f. 10 *a* and *b*, f. 11.

suggests, *A. hiemalis,* Salter, and a *A. Kockscharofi,* De Vern. and Keyserling, (*a*) are identical, we have to go still further back for a name.

AVICULOPECTEN, *sp.*

(Plate X., fig. 3.)

Obs.—A single imperfect internal cast of one valve differs from any *Aviculopecten* known to occur in our eastern beds, either Carboniferous or Permo-Carboniferous ; it is of the type of *A. villanus;* De Koninck (*b*) from the Carboniferous of Belgium. The valve is broadly obicular, moderately convex, with a long cardinal margin, and a flattened pointed posterior auricle, by no means large for the size of the valve, falciform-emarginate on its outer margin ; the anterior auricle and a portion of the anterior end are wanting. The posterior margin as a whole is strongly sigmoidal, and the umbo small and pointed. The costae are simple, to the number of sixteen, all primary, and crossed by several wide lati-laminae, particularly well marked on the posterior auricle.

GENUS CONOCARDIUM, *Bronn,* 1835.

(Lethaea Geognostica, 1835, I., p. 91.)

Obs.—An internal cast of a small shell represents this genus; the material is quite insufficient for description. Only one Australian Carboniferous or Permo-Carboniferous form is at present described —*C. australe,* McCoy—but the cast does not appear to be this species.

GENUS STUTCHBURIA, *Eth. fil.,* 1900.

(Rec. Austr. Mus., 1900, III., No. 7, p. 178.)

(Plate VII., figs. 7-10.)

Obs.—Two internal casts and a crushed testiferous example are probably referable to this genus.

The following Permo-Carboniferous species have already been placed in *Stutchburia,* viz. :—

1. *Orthonota* (?) *costata,* Morris.
    (= *Cardinia* (?) *costata,* Dana ; (?) *Cypricardia veneris* Dana ; *Pleurophorus Morrisii,* auct.).
2. *Orthonota compressia,* Morris.
3. *Modiolopsis simplex,* Dana.
    (= *Cypricardia simplex,* Dana.)
4. *Stutchburia farleyensis,* Eth. fil.

(*a*) De Verneuil and Keyserling—Murchison's Geol. Russia in Europe, 1845, ii., t. 20, f. 16.
(*b*) De Koninck—Faune Calc. Carb. Belgique, Pt. 5, 1885, t. 33, f. 7.

The succeeding five forms may be species of *Stutchburia,* viz.:—

1. *Cardinia* (?) *cuneata,* Dana.
2. *Cardinia* (?) *recta,* Dana.
    (= (?) *Cardinia* (?) *exilis,* McCoy.)
3. *Modiolopsis siliqua,* Dana.
    (= *Cypricardia siliqua,* Dana.)
4. *Pleurophorus biplex,* De Koninck.
5. *Pleurophorus Randsi,* Eth. fil.

The specimens represent transversely elongated, narrow, rather pod-shaped shells, with sub-terminal umbos, and very obtuse rounded posterior diagonal ridges. The articulus was edentulus, but the hinge plates were thickened. A strong anterior muscle scar was situated low down, but the posterior scar is much less apparent ; the pallial line was simple. The test bore distant concentric rugae, and there are certainly faint indications of radii on and following the direction of the posterior diagonal ridge, but not elsewhere ; I believe four of these radii existed.

It is almost impossible to determine the specific identity of these casts in their present condition, but it may be pointed out that they are certainly not *Stutchburia costata,* Morris, sp., *S. compressa,* Morris, sp., or *S. farleyensis,* Eth. fil. The outline very closely resembles that of *Stutchburia simplex,* Dana, sp., and had it not been for the posterior diagonal radii, I would have been content to here refer them, for Dana's species is non-radiate. The same holds good for the third of the "possible" species of *Stutchburia, Modiolopsis (Cypricardia) siliqua,* Dana ; with the two first of this series, Dana's *Cardiniae,* it is unnecessary to make any comparison. Of the two so-called *Pleurophori,* the present casts possess four diagonal radii in common with *P. Randsi* (*a*), as opposed to the two radii in *P. biplex* (*b*).

These specimens are very closely allied to *Pleurophorus Randsi,* mihi, if not identical with it, and in that case the latter becomes a *Stutchburia.*

The testaceous specimen is more or less encrusted with matrix, still there are traces of the diagonal radii as on the casts. It is, however, of further interest in that it exhibits the external features of the articulus. Immediately behind the umbos is a long and gradually widening escutcheon, the dorsal margin of each valve standing erect, as a dual crest in the middle line. The umbos are acute, directed downwards and overhanging a small lunule-like depression. The acquisition of this specimen necessitates an alteration in the generic definition of *Stutchburia,* by substituting external for internal ligament.

(*a*) Etheridge—Geol. Pal., Queensland, etc., 1892, t. 14, f. 14.

(*b*) De Koninck—Foss. Pal. Nouv.—Galles du Sud, Pt. 3, 1873, t. 19, f. 7.

GENUS BELLEROPHON, *De Montfort*, 1804. (*a*)

(Conch. Syst. 1804, I., p. 51.)

BELLEROPHON COSTATUS, *J. de C. Sby.*, var.

(Plate VII., figs. 11-15.)

Bellerophon costatus, J. de C. Sby., Min Conch. Gt. Brit., 1834. V., p. 110, t. 470, f. 4.

Bellerophon costatus, D'Orbigny, Férrusac and D'Orbigny's Hist. Nat. Céph. Acétab. Viv. et Foss., 1840, Atlas (Bellerophon) t. 1, f. 5 (excl. other figs.).

Bellerophon costatus, De Koninck, Faune Calc. Carb. Belgique, pt. 4, 1883, t. 39, f. 8-10.

Obs.—Four specimens of a small *Bellerophon* were collected at the Irwin River by Mr. Jackson, two are wholly internal casts, features are the globose form, semicircular, sublunate, or broadly and two partly the same and partly testiferous. The principal reniform aperture, depressed rounded dorsum of the preceding whorl projecting into the aperture, almost flat band, and well-defined narrow slit in the outer lip. The inner lip is greatly reflected, forming a highly developed callosity, which spreads some distance down the centre of the whorl, and extending over the small umbilicus forms a thick lateral projection on each side. The sculpture consists of flattened costae, springing at an acute angle from each side the band and then outwardly and posteriorly curved ; on passing over the band these costae assume a shallow and openly concave character. The internal casts are slightly angular in the middle line indicating the position of the band, more so indeed than would be anticipated from the flattened nature of the latter in the testiferous specimen.

In referring these fossils to *Bellerophon costatus,* I would call attention to the following facts :—In the original figure by Mr. J. de C. Sowerby, the thick lateral callosities are distinctly visible, accompanied by a flattened band, which Sowerby refers to as "undefined." The figures of D'Orbigny to which the name *costatus* is now restricted are copies of Sowerby's, line for line, but De Koninck's illustrations, both in his earlier (*b*) and later works, differ from Sowerby's and the West Australian specimens in so far that the alar callosities are not represented, although they exhibit the thickened lip and reflected callosity. Further, in the local shells, the crossing of the costae on the band does not exhibit the acute angle said to exist in European specimens of *B costatus.* With this trivial exception, and that of size, it is quite out of my power to suggest any points of departure of the Irwin River Bellerophons from the characteristic European species named.

(*a*) Restricted De Koninck, 1883.

(*b*) De Koninck—Descrip. Anim. Foss. Terr. Carb. Belgique, 1843, p. 343, t. 26, f. 2 *a-e*.

Other species bearing a very strong resemblance to the Australian are *B. sublævis*, Hall, as figured by White, (*a*) from the St. Louis Group of the American Sub-Carboniferous, and Toula's figure (*b*) of *B. hiulcus*, Martin, from the Carboniferous of Nova Zembla.

If the Irwin River fossils are *B. costatus,* then they must be regarded as forming a small race, with the slight varietal differences already pointed out.

One already described Australian form claims a moment's attention—*B. stanvelensis*, mihi. (*c*.) This possesses precisely the same form of callosity, but is a much larger shell, with an exsert keel, and the costae at right angles to the latter.

Mr. A. H. Foord provisionally recorded the presence of another well-known Carboniferous species, *B. decussatus,* Fleming, in the Irwin River beds, (*d*) with the following remarks :—"There are several examples, mostly of the young, of a shell very much like Fleming's species, but only one of these has the test remaining, and on this the ornaments are not quite satisfactorily preserved." Both *B. decussatus* and *B. costatus* to some extent resemble one another, and in the absence of the well-marked sculpture of the former, it is possible that the specimens submitted to Mr. Foord may be the present species rather than *B. decussatus*.

CEPHALOPODA.

Genus Gastrioceras, *Hyatt,* 1884.

(Proc. Boston Soc. Nat. Hist., 1884, XXII., p. 327.)

Gastrioceras Jacksoni, *sp. nov.*

(Plate IX., figs. 1-3.)

Sp. Chars.—Shell subglobose, deeply and widely umbilicate ; whorls at least five, semilunate in outline, much wider than high, with the dorsal excavations slightly less than half their height ; venter broadly rounded, continuous with the sides, which are slightly flattened, or very feebly convex around the umbilicus ; umbilicus deep and wide, with rounded steep whorl sides, a non-tuberculated margin, and at least five whorls exposed within ; sutures comparatively simple and spreading ; ventral or siphonal saddle apparently slightly bifid at its apex ; two first, or flanking lateral lobes slightly longer than the ventral saddle, rather pyriform in outline, and bent slightly outwards towards their subacute apices ; first lateral saddles wide and obtusely rounded at their apices, in fact they are the boldest and widest divisions of a sutural line ; second lateral lobes large like the first lateral saddles, but not as

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(*a*) White—11th Ann. Report Indiana Geol. Survey, 1882, p 359, t. 40, f. 5-7.
(*b*) Toula—Sitz. K. Akad. Wiss. Wien 1875, xxxi., Abth. 1, t. 1, f. 16 *a-c*.
(*c*) Etheridge—Geol. Pal. Q'land, etc., 1892, p. 289, t. 15, f. 11-13
(*d*) Foord—Geol. Mag , 1890, vii. (3), p. 154.

large, with generally obtuse, but slightly pointed apices ; third lateral lobes shallow and wide, the sutural line spreading outwards towards the edge of the umbilicus on each side.

Obs.—This is the largest Goniatite yet found in Australia, and of an entirely different type to the incomplete forms so far described. *G. Jacksoni* is of the type of *Goniatites Listeri,* Martin, sp., (*a*) and which is also the type species of *Gastrioceras.* It is less robust than, and not so broad as *Gastrioceras Listeri,* and does not bear tubercles. Whilst generally not unlike *G. carbonarium,* v. Buch, (*b*) the section of the whorls is far too sublunate, and the umbilicus more telescopic and deeper.

The body chamber in this specimen is only partially preserved and the aperture not at all, neither are there any traces of the test remaining.

Loc.—One and a quarter miles south-west of Gnoolowa Hill, Irwin River.

(*a*) Phillips—Geol. Yorkshire, Pt. 2, 1836, t. 20, f. 1 and 1*a*.
(*b*) Foord and Crick—Cat. Foss. Ceph. Brit. Mus., Pt. 3. 1897, p. 230, f. 110.

V.—Foraminifera from a Calcareous Marlstone, Gingin,

BY

WALTER HOWCHIN, F.G.S.,

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Note.—In 1904 a collection of fossils from the Chalk Pit, One Tree Hill, Gingin, was sent to Mr. Etheridge of Sydney, for examination and description. Mr. Etheridge's list of fossils is as follows, the initial figures in heavy type being the numbers under which the specimens are registered in the Geological Survey Museum :—

"**5551.**—Chert (?) semi-stalactite.

5552.— *Ostrea*, allied to *O. vesicularis,* Lamk.

5553.—Crushed Brachiopod, possibly a *Magellania.*

5554.—*Terebratulina* (?) This is quite distinct from any other described Australian Tertiary Brachiopod, and if examples can be obtained showing the interior is worthy of description.

5555.—*Serpula*, quite undescribed as an Australian form. It is allied to the European Tetiary, *Serpula bognoriensis,* Sby. Specimens are retained for description.

5556.—Spines of two species of echinids *Phyllacanthus.* Spines belonging to a species of this genus have been found in the Tertiary beds of Willunga, South Australia.

5557.—Portions of the shell of a bivalve, *Placunanomia.* Could a more or less perfect example be procured it would be worth description."

Commenting upon this collection, Mr Etheridge notes :—

> The fossils from One Tree Hill Chalk Pit are certainly not older than Tertiary, but the evidence is of too limited a nature to enable me to suggest an horizon within that great horizon, but I suspect the deposit must be well up in the series. For the sake of a name until more is known, call it Upper Tertiary. The condition of the fossils is not one that lends itself to accurate determination, but the *Terebratulina ?* (5554), *Serpula* (5555), and *Placunanomia* (5557) certainly seem to be new, and if additional specimens of the first and last can be obtained the whole are worthy of description.

A sample of the "chalk" (limestone) which it was proposed to utilise, with the addition of a little clay, in the manufacture of hydraulic cement, was analysed in the Survey Laboratory by Mr. E. S. Simpson in 1902 ; its composition proved to be :—

	Per cent.
Silica, SiO_2	15·09
Carbonic Acid, CO_2	33·02
Sulphuric Anhydride, SO_3	·13
Lime, CaO	42·41
Magnesia, MgO	1·32
Iron protoxide, FeO	1·16
Iron peroxide, Fe_2O_3	trace
Alumina, Al_2O_3	3·15
Water combined, H_2O	1·18
Water hygroscopic, H_2O	1·99
	99·45

A. GIBB MAITLAND,
Government Geologist.

FORAMINIFERA.

MILIOLIDÆ.

Miliolina oblonga, *Montag.*

Rare.

Range.—Eocene to Recent.

Spiroloculina (?) grata, *Terq.*

One fragment.

Range.—Late Tertiaries and Recent.

S. asperula, *Kar.*

Test finely arenaceous. The examples met with in the material are flat and outspread ; only the last two chambers indicated on surface by sutural lines. Common.

Range.—Miocene to Recent.

The *Miliolidae* are but feebly represented in the material.

LITUOLIDÆ.

Placopsilina vesicularis, *Brady.*

A singular occurrence, consisting of two chambers (one broken), parasite on a fragment of a large *Frondicularia.* The chambers are of unequal size, inflated, and bordered by an irregular margin of slightly raised shell-substance which supplied the pseudopodial apertures.

Range.—The type was obtained from the "Challenger" dredgings. Mr. F. Chapman has recorded this species from the Folkestone Gault, its only known occurrence, previously, in the fossil condition.

TEXTULARIIDÆ.

In point of numbers this Family is well represented in the material.

TEXTULARIA TROCHUS, *d'Orb.*

Several examples of this form were obtained, including one fine specimen.

Range.—Cretaceous to recent.

T. TURRIS, *d' Orb.*

Similar to preceding but elongate. Rare.

Range.—Cretaceous to Recent.

T. SAGITTULA, *Defrance.*

Small but well-formed specimens. Rare.

Range.—Cretaceous to Recent.

T. GLOBULOSA, *Ehr.*

A small neat Textularian with nearly spherical chambers. Rare.

Range.—Very common in Cretaceous, somewhat rare in Tertiary and Recent.

T. GIBBOSA, *d' Orb.*

Numerous examples referable to this type occur, and show much variation as to size, some being small and stunted, others longer and tapering. The last two chambers, in all cases, are larger and more inflated than the others. In a few instances the aboral extremity is acuminate.

Range.—Carboniferous to Recent.

VERNEUILINA SPINULOSA, *Reuss.*

Tricarinate and spinous. One example.

Range.—Cretaceous to Recent.

V. POLYSTROPHA, *Reuss.*

A small Verneuiline shell, occurs in considerable numbers. The chambers are less inflated than is usual in the above species, and the test is irregularly angular. It shows some affinities with *V. variabilis,* Brady, and is probably an intermediate variety.

LAGENIDÆ.

LAGENA HISPIDA, *Reuss.*

Test globular and hispid with a long neck. Rare.

Range.—Lias to Recent.

L. GLOBULOSA, (*U. & J.*)

Rare.

Range.—Silurian to Recent.

NODOSARIA CONSOBRINA, var. EMACIATA, *Reuss.*

A long, tapering, dentaline test, with numerous smooth chambers, which increase in their length towards the oral extremity. Common.

Range.—Cretaceous to Recent.

N. VERTEBRALIS, *Batsch.*

One or two fragments occurred, in the washings, of a Nodosarian with broad, sunken septa, composed of clear shell-substance, which are probably referable to this species, but they do not show the longitudinal costæ, or markings, which usually characterise the Recent forms.

Range.—Recent.

N. SOLUTA, *Reuss.*

Fragments were met with of a large dentaline test, composed of inflated chambers, which we assign to this species.

Range.—Cretaceous to Recent.

N. OBLIQUA, *Linne.*

A dentaline form, with fine longitudinal costæ. A single broken specimen.

Range.—Permian to Recent.

FRONDICULARIA INTERMITTENS, *Reuss.*

A single specimen of a very neat and perfect *Frondicularia,* which corresponds very closely with Reuss' species, as described and figured in "*Die Foram, u. Ostracoden d. Kreide am Kanara-See,*" obtained from Cretaceous beds, and described as "very rare." It is a small foraminifer, of the lanceolate type, mucronate at the aboral end, with inflated primordial chamber which is ornamented with longitudinal costæ. The segments are almost flush and septa are indicated by very fine striæ in slight depressions, they being intermittent with the smooth segments. The only point of difference between the present specimen and Reuss' figure is in its fewer chambers, the proportion being 6 and 8.

F. CHAPMANI, *Perner.*

A narrow tapering, many-chambered lanceolate test, chambers nearly flush and destitute of ornament. Several fragments.

Range.—Cretaceous.

F. GAULTINA, *Reuss.*

A perfect and rather fine example, probably belongs to this species, although it is much broader than Reuss' type, being half as broad as long. The test consists of a somewhat large primordial chamber and six segments. The sutures are very distinct and sunken. Test smooth. The peripheral margin of the aboral portion of the test is broadly crescentic.

Range.—Gault and Red Chalk.

FLABELLINA INTERPUNCTATA, *Von de Marck.*

Septation sharply defined by fine, raised lines. Shell more or less ornamented by small tubercles. One example and two fragments.

Range.—Cretaceous.

MARGINULINA COSTATA, *Batsch.*

Robust and characteristic examples. Moderately common.

Range.--Trias to Recent.

CRISTELLARIA ROTULATA, *Lamk.*

Common in the washings, including some fine examples.

Range.—Lower Silurian to Recent.

C. CULTRATA, *Mont.*

Common, including some very fine samples of the "keel," which in some specimens equals one-third of the diameter of the shell.

Range.—Lias to Recent.

C. ORBICULARIS, *d' Orb.*

The "keeled" examples of *Cristellaria* in the material show considerable variation in the number of segments and the extent of curvature which they exhibit. Some of those which show the greatest measure of vortical arrangement of the chambers might be referred to this species. Rather scarce.

Range.—Miocene to Recent.

C. ACUTAURICULARIS (*F. & M.*)

A thick and somewhat elongated form, with large, broad, and nearly flat septal face. Characteristic examples, moderately common.

Range.—Lias to Recent.

C. OVALIS, *Reuss.*

A rotundate and pyriform variety of the genus. Rare.

Range.—Gault and Upper Cretaceous.

GLOBIGERINIDÆ.

GLOBIGERINA BULLOIDES, *d' Orb.*

Very common, with many fine examples.

Range.—Cambrian of New Brunswick (Canada), to Recent.

G. CRETACEA, *d' Orb.*

A few examples of this neat little species were obtained.

Range.—Cretaceous to (?) Recent.

G. LINNÆANA, *d' Orb.*

This is one of the most interesting forms in the material. Specimens attain a fair size and are very common. The roughness of surface, which is characteristic of this species, in some examples, becomes distinctly hispid in its features.

Range.—Red Chalk, Chalk, Suffolk Crag, and (?) Recent.

ROTALIIDÆ.

DISCORBINA OPERCULARIS, *d' Orb.*

Test thin, slightly convex on superior surface, with numerous arcuate segments. The examples are small and delicate, but perfectly characteristic. Rather scarce.

Range.—d' Orbigny found the type form in littoral sands of the West Indies. The "Challenger" obtained it in four localities, limited to Australian waters. The only record in a fossil condition, so far as I know, is in the upper Bed (Miocene) of Muddy Creek, Victoria, where it is rather scarce.

TRUNCATULINA LOBATULA (*U. & J.*).

Rare.

Range.—Carboniferous to Recent.

T. VARIABILIS, *d' Orb.*

Examples of irregular growths ("wildgrowing") often occur associated with *T. lobatula,* and are included under d' Orbigny's type. A few of this variety were observed in the material examined.

Range.—Cretaceous to Recent.

ROTALIA BECCARII, *Linne.*

Small examples. Rare.

Range.—Jurassic to Recent.

R. BROECHIANA, *Kar.*

Similar to preceding but a thicker shell, with taller spire, and rather fewer chambers shown on inferior surface. Rather scarce.

Range.—Tertiary and Recent.

R. SOLDANII, *d' Orb.*

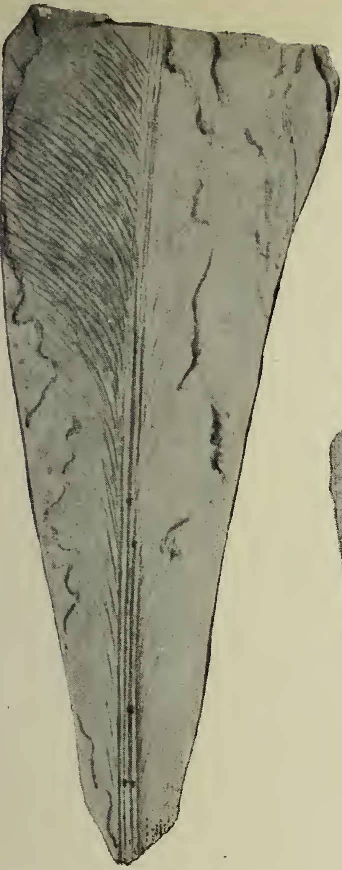
A single small example.

Range.—Oligocene to Recent.

NONIONINA ASTERIZANS (*F. & M.*)

A nautiloid shell exhibiting exogenous growth of shelly substance at umbilicus. Single example.

Range.—Eocene to Recent.



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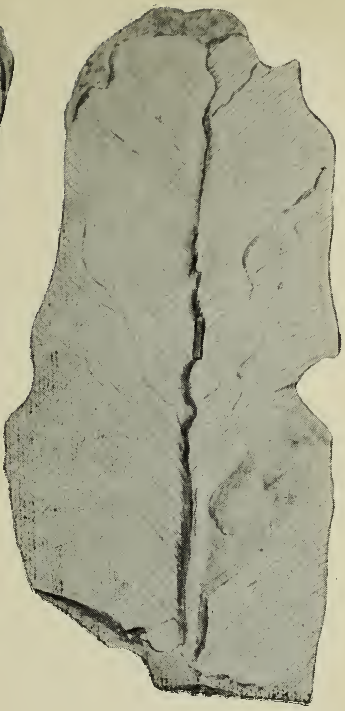

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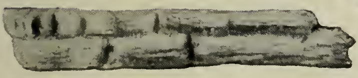

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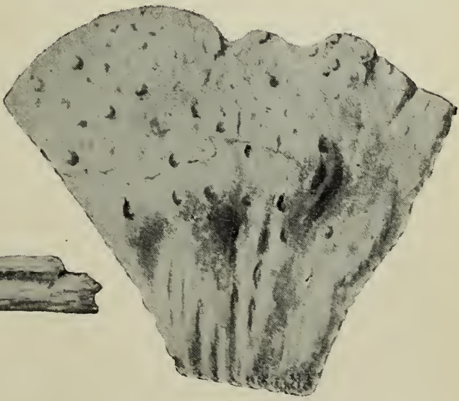

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F.C., Del.

Plate I.

PLATE I.

GLOSSOPTERIS BROWNIANA, *Brongniart.*

Fig. 1.—Portion of a leaf with peculiar pittings on the midrib. Natural size.

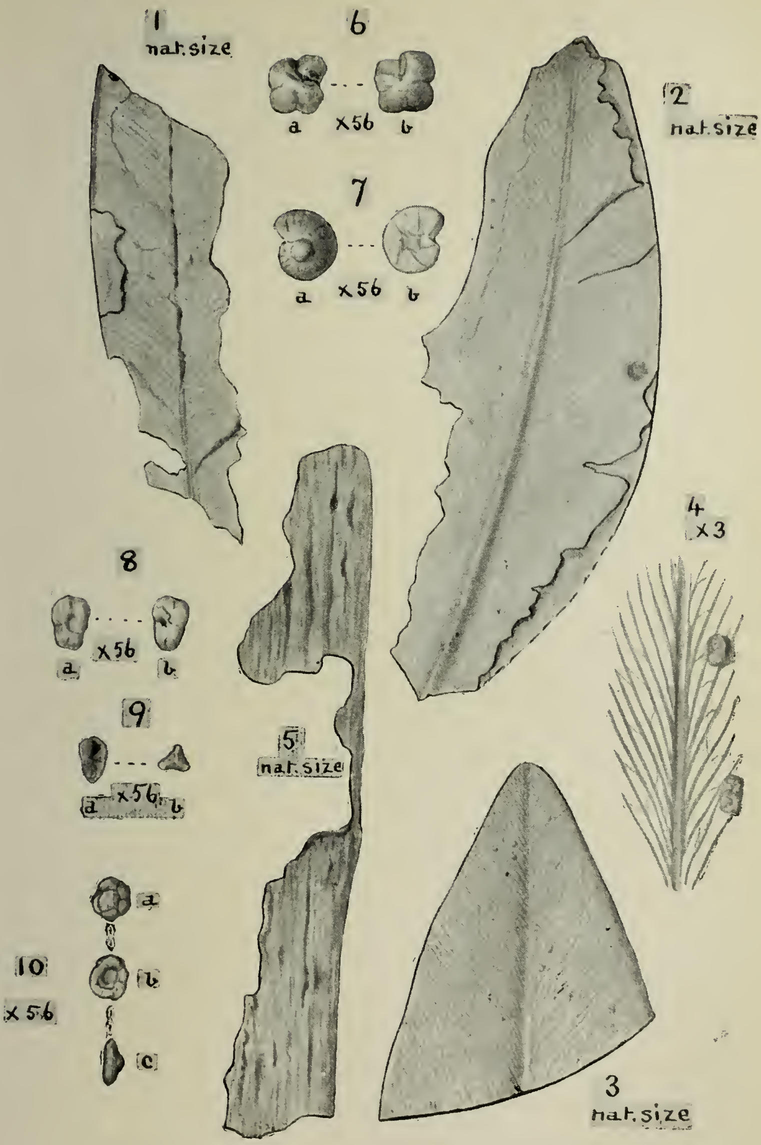
GLOSSOPTERIS INDICA, *Brongniart.*

„ 2.—Portion of a leaf, with indication of a rounded apex, and having a closely parallel venation. Natural size.

GLOSSOPTERIS RHIZOME (VERTEBRARIA).

„ 3.—A fragment on a bore-core. Natural size.

„ 4.—? Rhizome of a fern, and probably allied to RHIZOMOPTERIS— × 2.



F.C., Del.

Plate II.

PLATE II.

GLOSSOPTERIS ANGUSTIFOLIA, *Brongniart.*

Fig. 1.—Portion of a leaf. Natural size.

GLOSSOPTERIS INDICA, *Brongniart.*

„ 2.—Leaf, natural size.

GLOSSOPTERIS GANGAMOPTEROIDES, *Feistmantel.*

„ 3.—Apical half of a leaf, showing ? fructification on the surface of the leaf near the midrib. From a bore-core. Natural size.

GLOSSOPTERIS GANGAMOPTEROIDES, *Feistmantel.*

„ 4.—A portion of the leaf shown in fig. 3, magnified, to more clearly indicate the character of the supposed fructification— × 3.

„ 5.—A stem-like fragment of doubtful affinity. Natural size.

PULVINULINA *cf.* EXIGUA, *Brady.*

„ 6.—*a.* Superior aspect. *b.* Inferior aspect— × 56.

TRUNCATULINA HAIDINGERI, *d'Orbigny sp.*

„ 7.—*a.* Superior aspect. *b.* Inferior aspect— × 56.

(?) ENDOTHYRA *sp.*

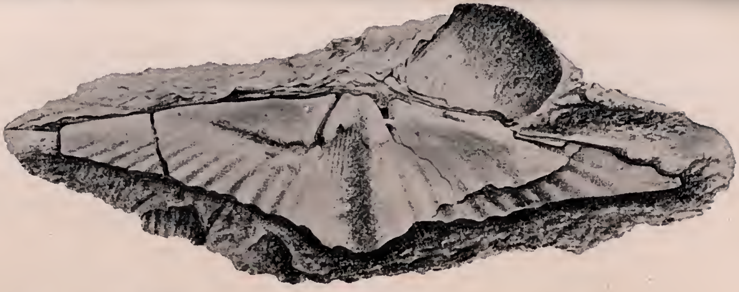
„ 8.—*a.* Superior aspect. *b.* Inferior aspect— × 56.

BULIMINA *sp.*

„ 9.—*a.* Lateral aspect. *b.* Terminal aspect— × 56.

VALVULINA PLICATA, *Brady.*

„ 10.—*a.* Superior aspect. *b.* Inferior aspect. *c.* Peripheral aspect— × 56.



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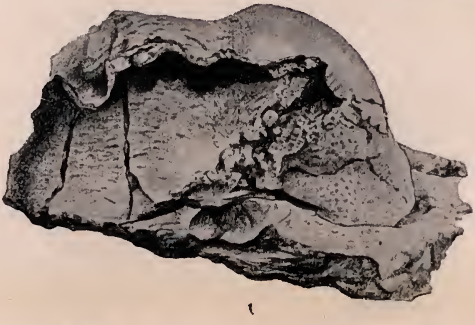

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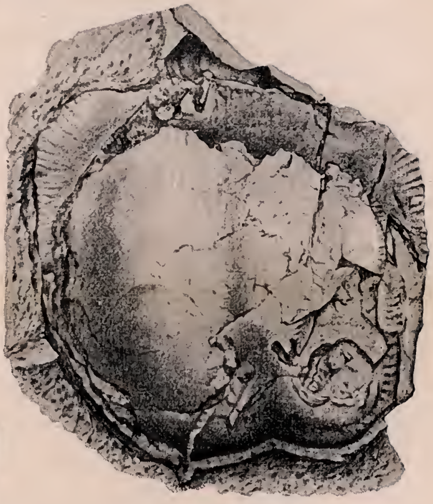

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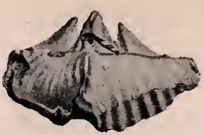

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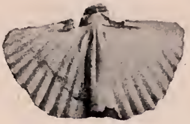

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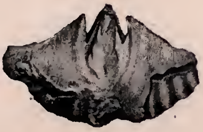

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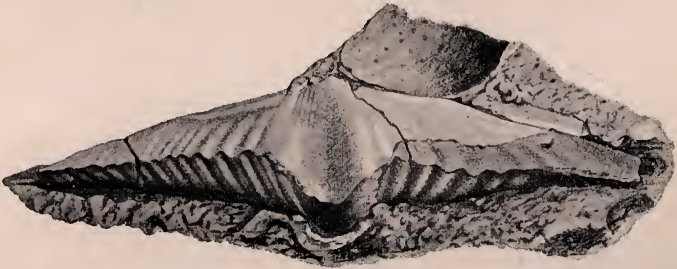

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Frank R. Leggatt, Del.

Plate III.

PLATE III.

Spirifera avicula, *G. B. Sby.*

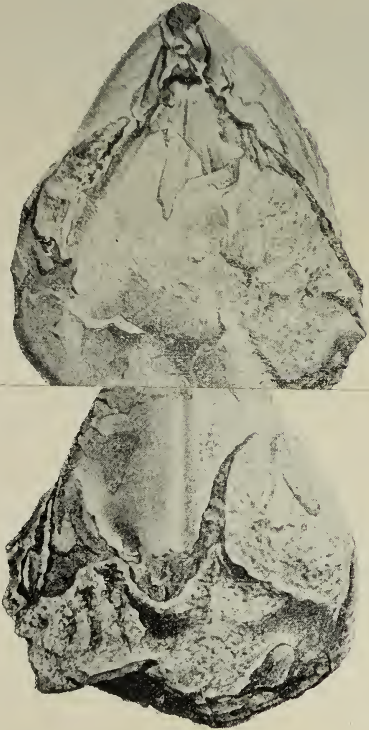
Fig. 1.—Internal cast of portions of the united valves.
„ 2.—Internal cast of the pedicle valve.

Spirifera, *sp. ind.*

„ 3.—Internal cast of the brachial and umbonal regions of the pedicle valves.
„ 4.—Internal casts of the brachial valve, with the cardinal slopes of the pedicle valve removed.
„ 5.—Internal cast of the pedicle valve.

Productus subquadratus, *Morris.*

„ 6.—Exfoliated and partial internal cast of the pedicle valve.
„ 7.—The same seen from the dorsal aspect showing the impression left by the area of the brachial valve.



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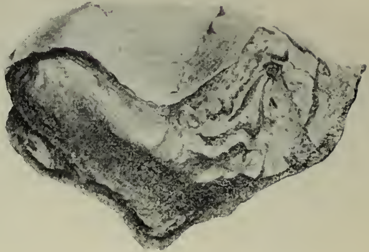

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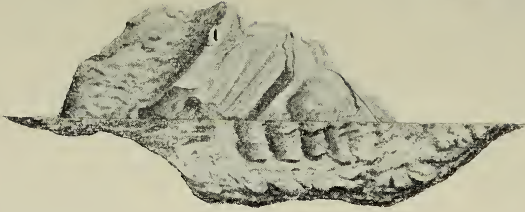

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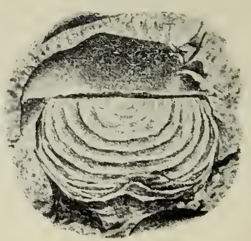

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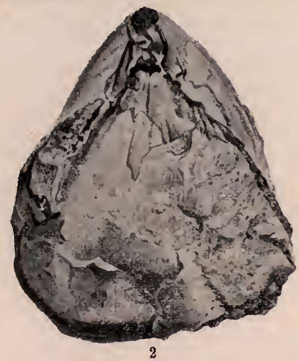
Plate IV.



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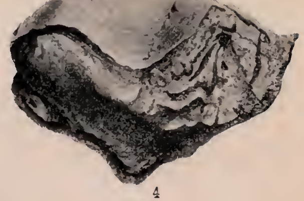

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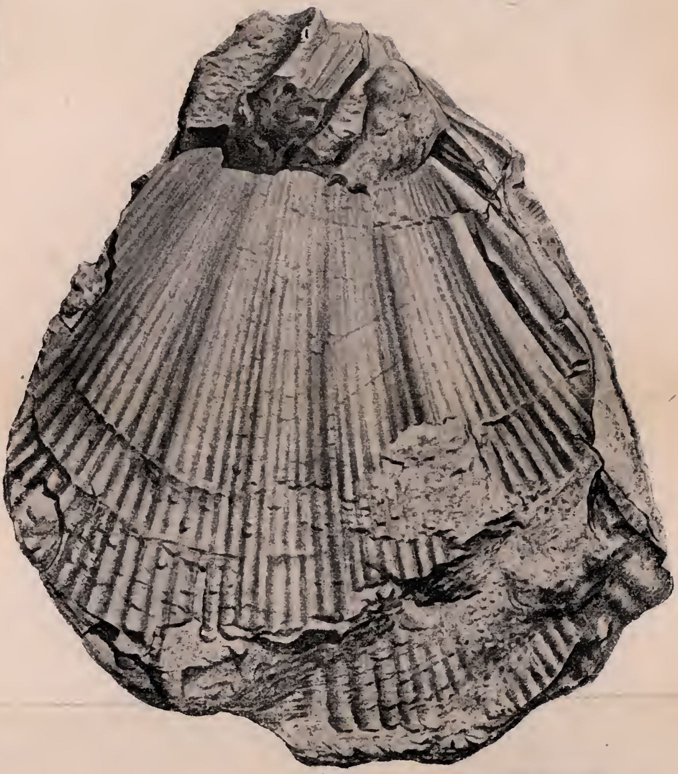

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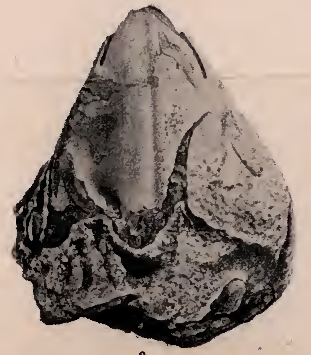

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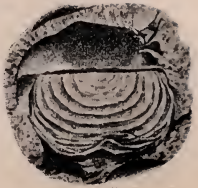

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Plate IV.

PLATE IV.

AVICULOPECTEN, *sp. ind.*

Fig. 1.—Partial external cast of a large species, with coarse costæ grouped in obtusely rounded fasciculi.

DIELASMA NOBILIS, *Eth. fil.*

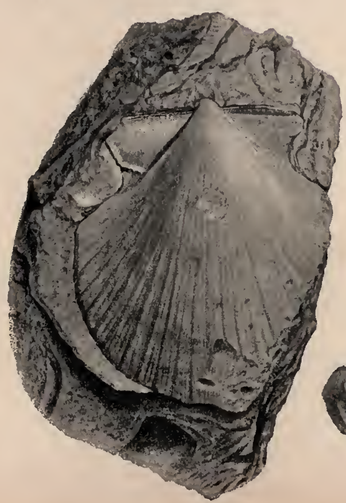
„ 2.—Internal cast of the united valves.

„ 3.—Internal cast of the pedicle valve.

„ 4.—Internal cast of the united valves, ventral view.

CHONETES, *sp. ind.*

„ 5.—Impression of a part of the pedicle valve above, and exfoliated cast of the brachial valve below.— × 2.



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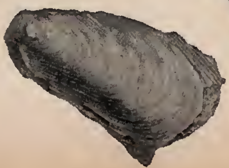

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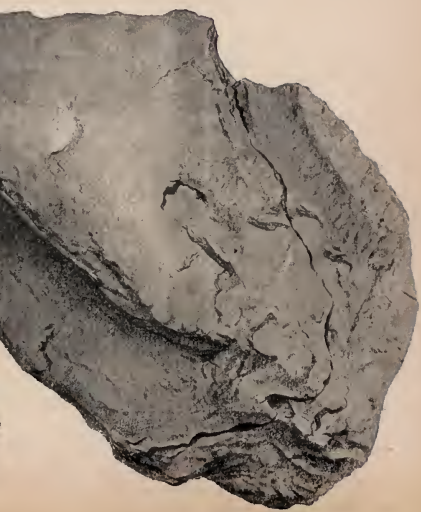

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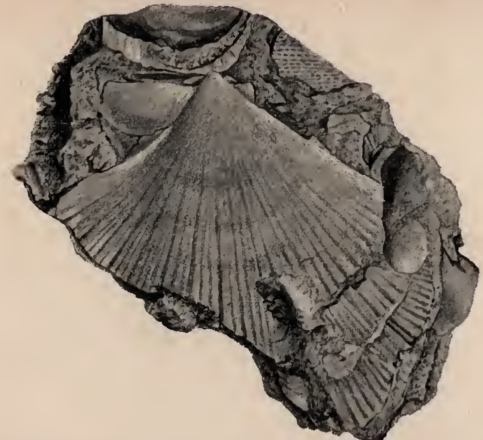

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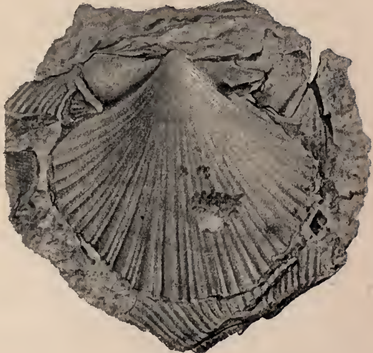

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Plate V.

PLATE V.

Deltopecten subquinquelineatus, *McCoy?*

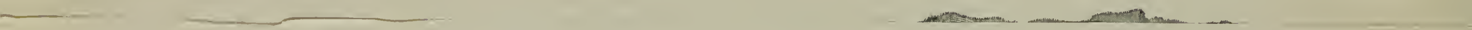
Fig. 1-3.—Internal casts of three valves in various stages of preservation. In Fig. 1 are visible traces of resilium furrows along the cardinal margin; and in Fig. 3 is to be seen the cast of the resilifer behind the umbo.

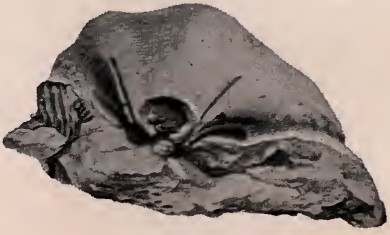
Myalina (?) mingenewensis, *Eth. fil.*

„ 4.—Internal cast of a large mutilated left valve.

Modiola (?), *sp. ind.*

„ 5.—Cast of a nearly complete left valve.

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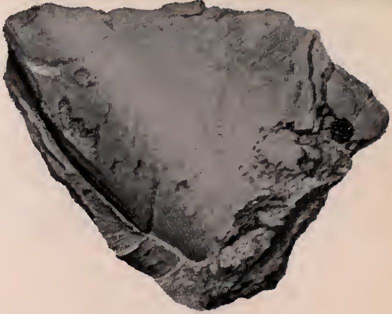
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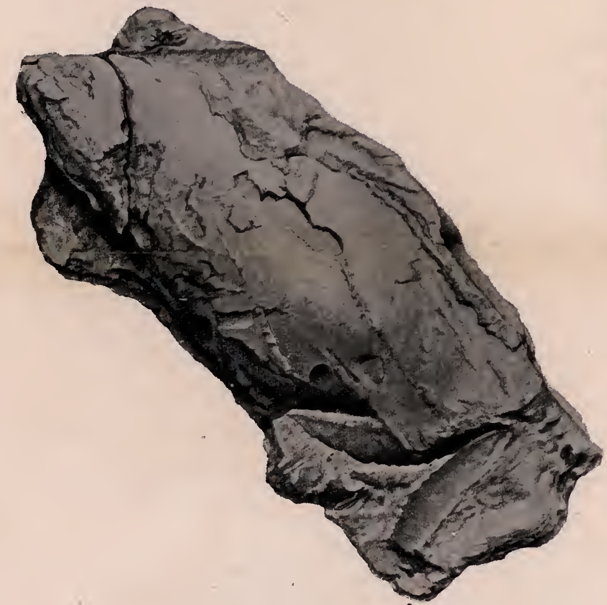
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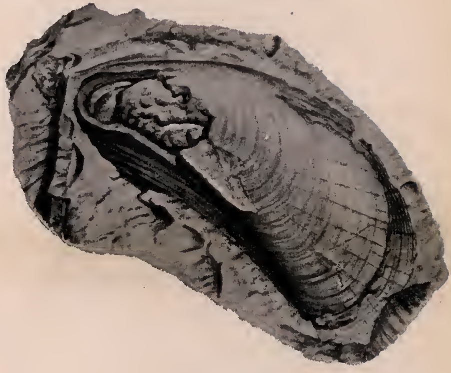
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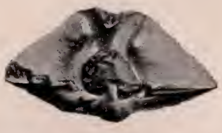
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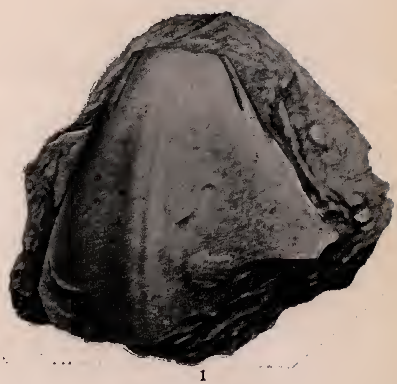
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Plate VI.

PLATE VI.

DIELASMA NOBILIS, *Eth. fil.*

Fig. 1.—A partial internal cast of the pedicle valve, exhibiting the dental plate fissures and the trilobation of the valve.

„ 2.—Internal cast of the dorsal portion of the pedicle valve, with the large foramen and the dental plate fissures.

MYALINA (?) MINGENEWENSIS, *Eth. fil.*

„ 3.—Mutilated internal cast of a left valve.

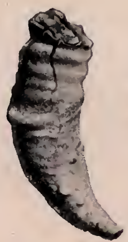
„ 4.—Imperfect internal cast of a left valve, possibly this species.

MODIOLA (?), *sp. ind.*

„ 5.—Internal cast of the left valve, probably the more mature form of the specimen represented in Pl. V., f. 5.

SPIRIFERA, *sp. ind.*

„ 6.—Internal cast of the united valves, dorsal view of the specimens represented in Pl. I., f. 3-5.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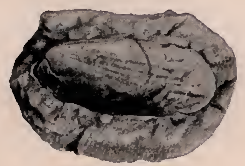
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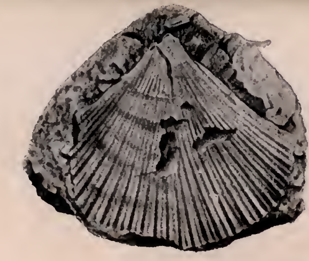
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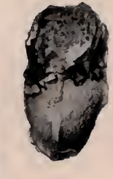
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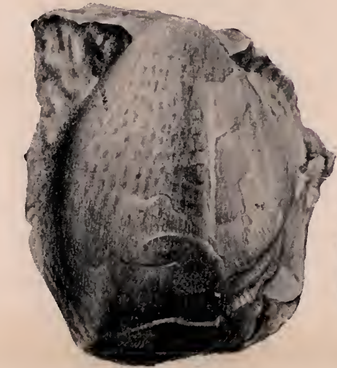
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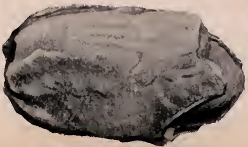
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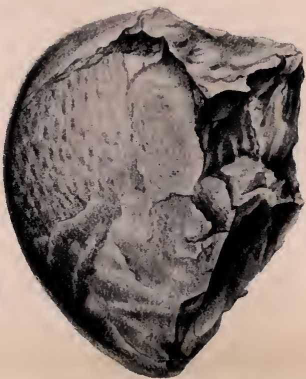
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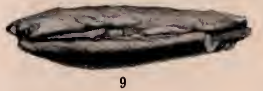
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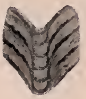
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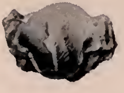
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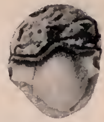
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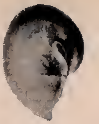
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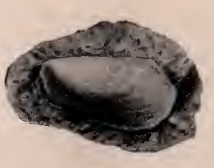
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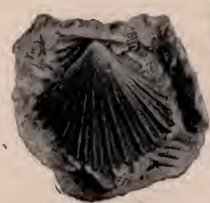
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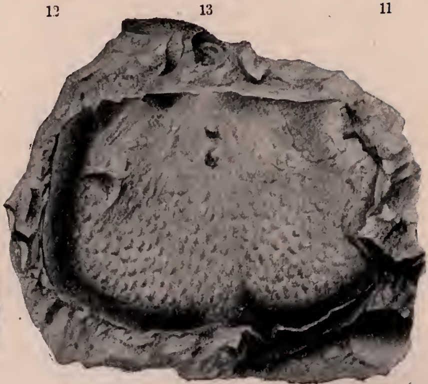
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Plate VII.

PLATE VII.

PLEUROPHYLLUM AUSTRALE, *Hinde.*

Fig. 1.—Corallum, side view.

PRODUCTUS SUBQUADRATUS, *Morris.*

„ 2.—Pedicle valve, front view.

„ 3.—Pedicle valve, side view.

„ 4.—Brachial valve.

AVICULOPECTEN SPRENTI, *Johnston.*

„ 5.—Imperfect and exfoliated valve, with primary and secondary costæ.

„ 6.—Smaller testaceous example with the auricles partially preserved, and a much less number of primary and secondary costæ.

STUTCHBURIA, *sp.*

„ 7.—Partially testaceous left valve, allied to *S.* ? (*Pleurophorus*) *Randsi*, Eth. fil.

„ 8.—Internal cast of a left valve.

„ 9.—United valves and dorsal margins of specimen Fig. 7.

„ 10.—Internal cast of a smaller left valve.

BELLEROPHON COSTATUS, *J. de C. Sby.*, *var.*

„ 11.—Side view of a partially testaceous example.

„ 12.—The same specimen showing a portion of the test with the band and its sculpture.

„ 13.—The same specimen exhibiting the mouth and thickened alar expansions.

„ 14.—An internal cast displaying the band in relief.

„ 15.—A portion of the band and sculpture of Fig. 12, enlarged.

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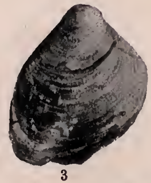

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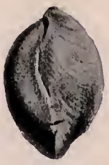

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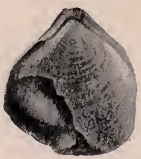

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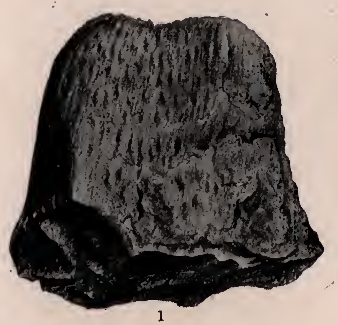

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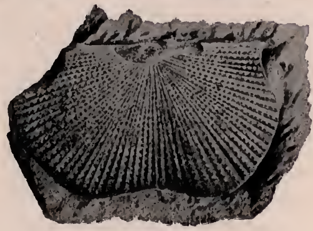

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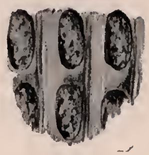

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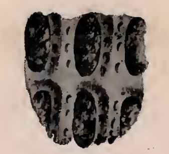

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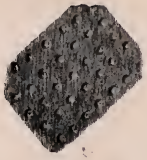

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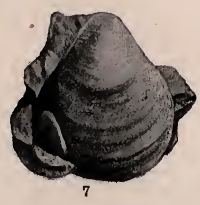

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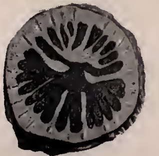

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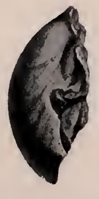

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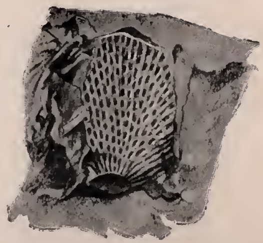

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Plate VIII.

PLATE VIII.

PRODUCTUS SUBQUADRATUS, *Morris.*

Fig 1.—Pedicle valve seen from the front.

CHONETES PRATTI, *Davidson.*

„ 2.—Nearly perfect pedicle valve, with spine bases on the costæ— × 3.

SEMINULA SUBTILITA, *Hall* (?)

„ 3.—Pedicle valve— × 2.

„ 4.—Brachial valve, with umbo of pedicle valve— × 2.

„ 5.—United valves, side view— × 2.

„ 6.—Test, showing silky, fibrous structure, highly magnified.

DIELASMA, *sp.*

„ 7.—Pedicle valve— × 2.

„ 8—Pedicle valve, side view— × 2.

„ 9.—Test, showing punctæ, highly magnified.

PLEUROPHYLLUM AUSTRALE, *Hinde.*

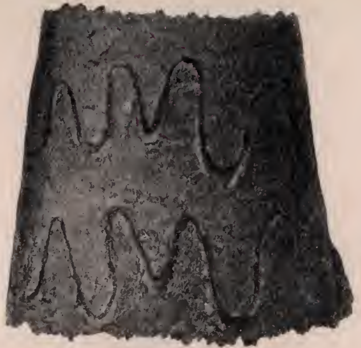
„ 10.—Natural fractured section of a corallum, showing the theca thickened by stereoplasma; a small cardinal septum, and the counter septum united with the four alar septa on each side into a subcentral stereoplasmic mass— × 2.

FENESTELLA FOSSULA, *Lonsdale.*

„ 11.—Polyzoarium, portion of.

„ 12.—Obverse, with from three to four zœcia on the interstices on each side a fenestrule— × 5.

„ 13.—Obverse, with striæ on the interstices— × 5.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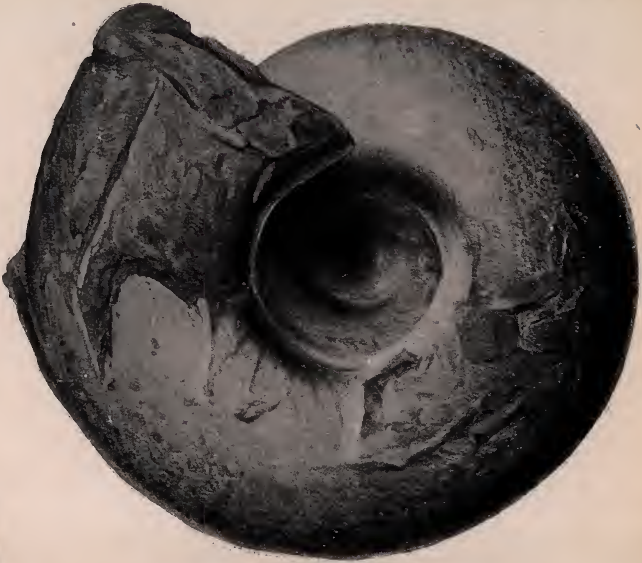
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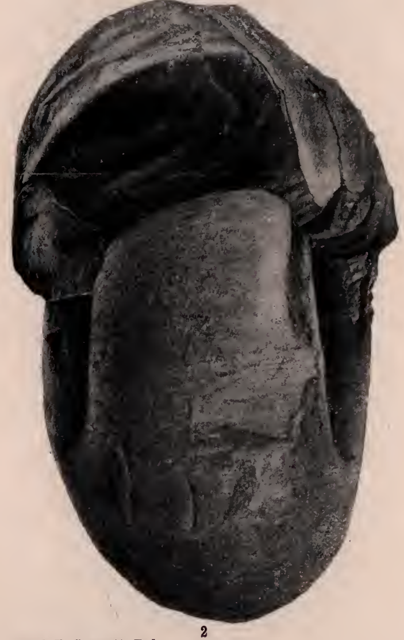
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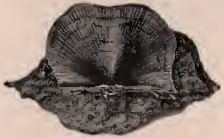
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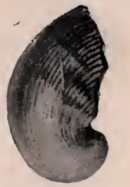
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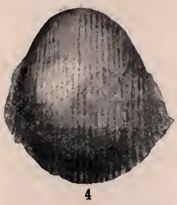
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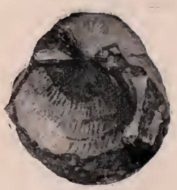
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Plate IX.

PLATE IX.

GASTRIOCERAS JACKSONI, *sp. nov.*

Fig. 1.—Side view, showing the deep umbilicus.

„ 2.—Front view, exhibiting the width of the dorsum, and sectional outline of the whorls.

„ 3.—Two sutures with lobes and saddles.

PRODUCTUS TENUISTRIATUS, *var.* Foordi, *Eth. fil.*

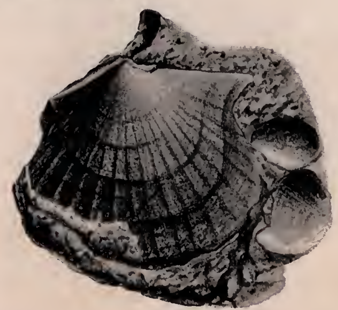
„ 4.—Front view of the pedicle valve.

„ 5.—Side view of the pedicle valve.

„ 6.—The brachial valve, and umbo of the pedicle valve.

CHONETES PRATTI, *Davidson.*

„ 7.—The brachial valve, with its delicate costæ, and the dorsal margin bearing broken spines.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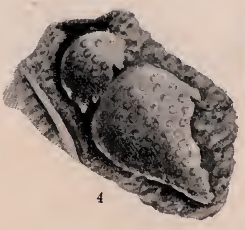
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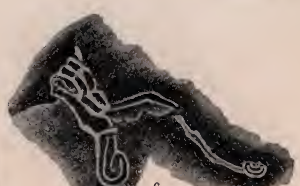
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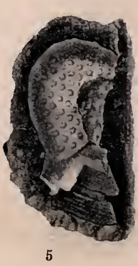
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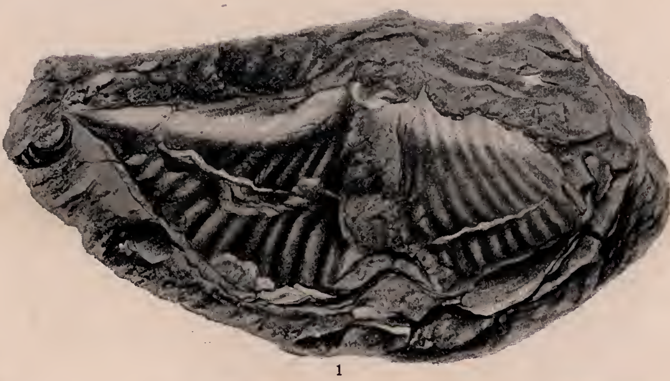
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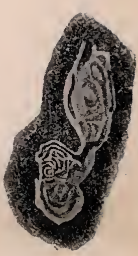
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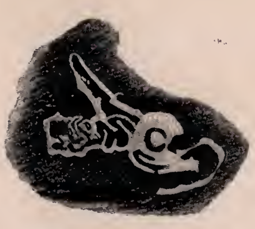
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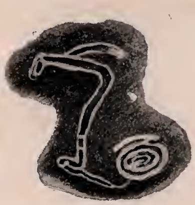
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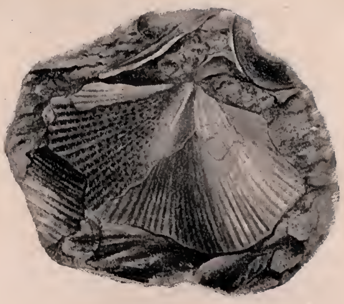
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Plate X.

PLATE X.

SPIRIFERA, *sp.*

Fig. 1.—Valve of a large *Spirifera*, with coarse undivided costæ.

CHONETES PRATTI, *Davidson.*

„ 2.—Pedicle valve, partly testaceous with perforations in the valleys between the costæ—× 3.

AVICULOPECTEN, *sp.*

„ 3.—Internal cast of an *Aviculopecten* after the type of *A. villanus*, De Kon.

NUBECULARIA STEPHENSI, *Howchin.*

„ 4.—Exterior view showing granular ornament—× 12 (approx.)

„ 5.—Portion of another similar individual, on the interior of a valve of *Aviculopecten*—× 12 (approx.)

„ 6.—A partly spirilline and party rectilinear example in section on the exterior of an *Aviculopecten*—× 12 (approx.)

„ 7.—Two more or less spirilline examples in section, apparently united, and on the surface of an internal cast of a bivalve—× 12 (approx.)

„ 8.—More or less spirilline specimen in section on the same bivalve as Fig. 7—× 12 (approx.)

„ 9.—Spirilline and rectilinear conditions, with traces of septa in the latter; on the same bivalve as Figs. 7 and 8—× 12 (approx.)

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